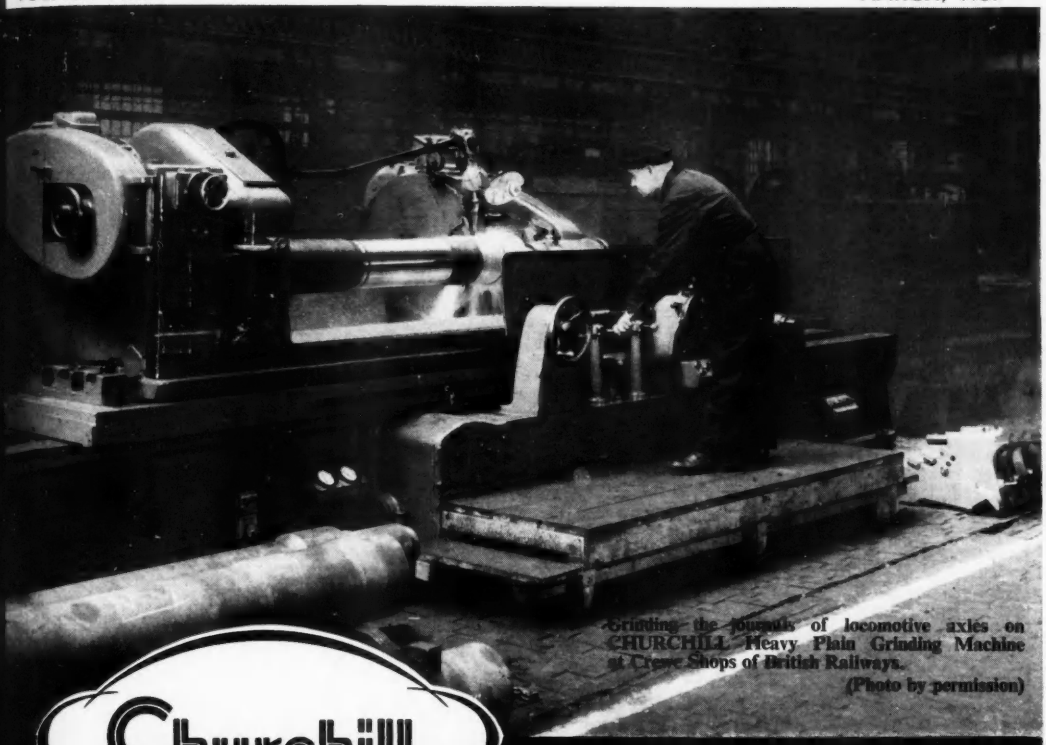
The

ENGINEERS' DIGEST

APR 13 1959
ENGINEERING

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XX No. 3 MARCH, 1959



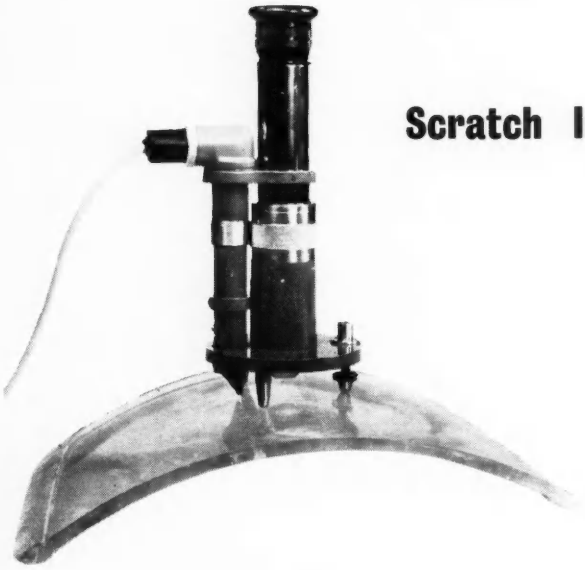
Grinding the journals of locomotive axles on CHURCHILL Heavy Plain Grinding Machine at Crewe Shops of British Railways.
(Photo by permission)

Churchill

E CHURCHILL MACHINE TOOL CO. LTD., BROADHEATH, MANCHESTER

port Sales Organisation: Associated British Machine Tool Makers Ltd., London, Branches and Agents.
me Selling Agents: Charles Churchill & Co. Ltd., Birmingham and Branches.

PRECISION *plus* PRODUCTION



Scratch Investigation Microscope

A small portable instrument for measuring the depth of scratches on a flat or curved surface.

The microscope stands directly on the surface and the depth of scratch is read to 0·001 in. on a simple scale seen in the eyepiece; lesser amounts can easily be estimated.

Illumination is either by a small portable battery or from the mains and the microscope can be used indoors or in the open.

Photographic records can be made on 35 mm. roll film with a camera attachment. Height: $7\frac{3}{4}$ in.; weight: 2 lb.

Write for list b24.

HILGER & WATTS

HILGER & WATTS LTD, 98 ST PANCRAS WAY, LONDON NW1 *Tel: GULliver 5636*

now
WRITE FOR A NEW BOOKLET

"Cronite"
REGD. TRADE MARK

The **HIGH TEMPERATURE ALLOY**

SALT, LEAD AND CYANIDE VESSELS
CARBURIZING BOXES AND POTS
ROTARY RETORTS & PROPELLING WORMS
FURNACE HEARTHS AND FITTINGS
ENAMELLING PERRITS AND SUPPORTS
GLASS-BLOWING NOZZLES
PYROMETER PROTECTION SHEATHS
CASTINGS FOR USE AT 700 1200 C.

The
CRONITE FOUNDRY Co. LTD
LAWRENCE RD·TOTTENHAM·LONDON.N15
PHONE·STAMFORD HILL 4237

CONTENTS

	Page
The Minidigest	A2
The Blue Pages	103
Visco-Elasticity in Lubrication	107
High-Productivity Milling Cutters	109
Phase-Contrast Techniques in Metallurgical Microscopy	110
Influence of the Peltier Effect in Resistance Welding	113
Motion-Picture Technique for Studying Grinding Phenomena	115
Properties and Applications of Molybdenum Coatings	117
The Fatigue Strength of Flame-Cut Steel Specimens Repaired by Welding	120
British Industrial Developments	125
Additional Abstracts	129
New Materials, Processes, and Equipment	131
News of the Month	134
Latest Industrial Literature	A83

The ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XX NO. 3 MARCH, 1959

EDITORIAL AND ADVERTISING OFFICES :

GREAT BRITAIN
120 Wigmore Street, London, W.1
Telephone : WELbeck 9357 & 6263

U.S.A.
366 Madison Avenue, New York 17, N.Y.
Telephone : MUrray Hill 2-8865

FRANCE
102 Rue Amelot, Paris (XI^e)
Telephone : VOL. 29-19

ITALY
Via degli Orombelli, 13, Milan
Telephone: 23.16.72

Annual Subscription Rates :
£2 2s. 0d. in the Sterling area, $7.50 in the Dollar area

Printed in Gt. Britain by THE ALCUIN PRESS, Welwyn Garden City, Hertfordshire, and published monthly by the proprietors, ENGINEERS' DIGEST LTD., 120 Wigmore Street, London, W.1

PITMAN | **technical books**

THE HEAT-TREATMENT OF STEEL

By Edwin Gregory, Ph.D., etc., and Eric N. Simons. New and up-to-date 2nd Edition. Covers every phase of the subject from principles to practice. It is very easy to read and explains what has to be done to different steels and why it is necessary. Recent developments are dealt with. 35/- net.

STRUCTURAL MECHANICS

By W. Morgan, B.Sc., etc., and D. T. Williams, A.M.I.Struct.E. etc. This new book commences at the beginning of the subject and treats its fundamental principles with the simplest mathematics. With problems included, it is suitable as a first course in Structures for all students of architecture, building, surveying and engineering. 30/- net.

THE SCIENTIFIC BACKGROUND
A Prose Anthology

By A. Norman Jeffares and M. Bryn Davies. It is a fact that during recent years there has been a deterioration in the ability to use language as a precise instrument. With a valuable introductory section and 100 carefully chosen extracts from the works of outstanding scientists, this book shows that good scientific prose is good English prose. 21/- net.

FINITE DIFFERENCE EQUATIONS

By H. Levy, D.Sc., etc., and F. Lessman, Ph.D., etc. Nowadays, a detailed examination and mastery of the Finite Difference Equation is of the first importance to all final-year and graduate mathematicians, mathematical physicists and engineers, and actuarial students and actuaries. This new book presents a practical treatment of such equations and their general method of solution. 37/6 net.

CHRISTIAN PRINCIPLES IN INDUSTRY

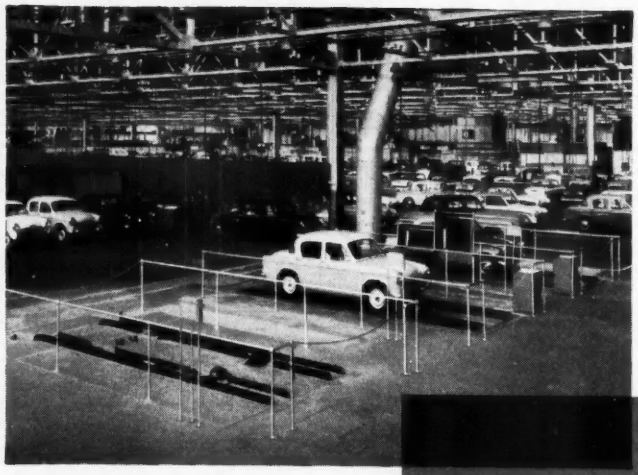
By C. H. Northcott, M.A., etc. This book defines and interprets Christian principles in terms of modern thought, and in their application to human relations in industry. It forms a brilliant analysis and criticism of business organization in its concept of direction and control of labour. 15/- net.

ENGINEERING OPTICS
The Principles of Optical Methods in Engineering Measurement

By K. J. Habell, M.Sc.(Lond.), etc., and A. Cox, B.Sc.(Dunelm), etc. An up-to-date guide to optical methods and instruments in their application to engineering measurement. Contains much practical as well as theoretical information. 40/- net.

From all booksellers

PARKER ST., KINGSWAY, LONDON, WC2



This car testing machine is operated by Keelavite hydraulics. It is installed at the Rootes Group Ryton factory.

HYDRAULICS IN ENGINEERING

We at Keelavite are a team of experts in the design, installation and maintenance of complete hydraulic systems. We are ready to accept full responsibility for the proper working of all our installations, including all electrical or other control equipment.

Not only this, we are the manufacturers of the largest range of hydraulic units in the United Kingdom.

We are, of course, fully experienced in special applications of hydraulic power for the engineering industry.

KEELAVITE
Hydraulics
GENERAL ENGINEERING DIVISION

THE RECOGNISED AUTHORITY

KEELAVITE HYDRAULICS LIMITED
ALLESLEY, COVENTRY Telephone: Meriden 441

THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

• *CONTINUOUS HORIZONTAL CASTING OF METALS*

A new method for the continuous horizontal casting of metals, especially aluminium and its alloys, can be used for the production of ingots of average length or of great length, and also permits the casting of bars of small section or wires. The equipment comprises a liquid-metal container which, in its lower part, has an opening communicating with a horizontal chill mould. From the moulds the metal passes out over a flat surface and between two walls in the shape of a flat U which gives the metal sufficient time to cool down and to take the form of a straight bar or rod before it is taken off on a roller-type conveyor track. In this way, crinkling and curving of the lower surface of the ingot are prevented. The ingot is carried away by means of a tractor plug, which has the same cross-section as the ingot to be cast and which has a cavity formed as a dovetail in its central portion. This plug is initially located at the orifice of the container and receives the liquid metal, which passes into the dovetail, where it solidifies. The plug is then drawn over the rollers, thus drawing along the ingot as it is progressively formed. As the metal, at the point where it has just become solidified by contact with the chill mould, is inherently fragile, there is a danger that surface defects will be caused. Moreover, there is the risk of remelting in this region, owing to the fact that the metal comprising the core of the ingot is still in a liquid state at this point. It is therefore necessary to make the zone in which the metal becomes detached from the mould wall as short as possible, and this is achieved by using an intensely cooled short chill mould.

• *MAGNESIUM OXIDE COLD CATHODES AS ELECTRON SOURCES*

The use of magnesium oxide cold cathodes as a new electron source is now being developed. The suitability of magnesium oxide as a cathode material was discovered when thin magnesium oxide layers were deposited on a nickel base and bombarded with electrons possessing sufficient energy to produce secondary electron emission from the magnesium oxide. When the bombarding beam was turned off, the magnesium oxide layer continued to emit electrons without external stimulus. Neither heat nor external light is necessary to keep the emission current alive. By varying the voltage at the collector electrode, this self-sustained current can easily be controlled for many hours from a few microamperes to several tens of milliamperes. The power required to run one magnesium oxide cathode is only 10% of that required for a conventional hot cathode, magnesium oxide cold cathodes requiring only 0·75 W per cathode. This figure refers to cathode power only, and not to plate or total power, the plate power being the same for one cold-cathode tube as for one thermionic tube. For a cold-cathode tube no filament transformer or separate battery is required. The cathode itself can be run on a small portion of the d.c. supply used for the total operation of the tube. Magnesium oxide cathodes are quick-starting and have a long life, but require a minimum voltage of about 300 V. As the tubes are not self-starting, means of starting must be provided. Development is now under way of a cold-cathode electron gun for use in cathode-ray tubes for television, and in klystrons, travelling-wave tubes, etc. A flat, picture-on-the-wall display device for television or radar is reported to be in the design stage, and it is possible that it may produce greater brightness than present pictures tubes.

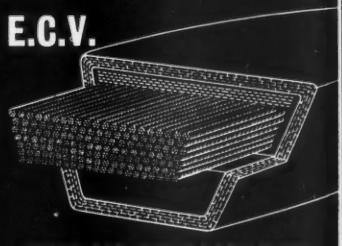
• *INCREASING THE CAPACITY OF SUBMARINE TELEPHONE CABLES*

It is reported that a new system capable of doubling the number of telephone conversations carried by undersea cables is being developed. In a normal two-way telephone conversation, each person is actually speaking only about half the total time, and even while speaking, there are significant gaps and pauses in his speech. Thus, if the two directions of transmission are separated, each transmission path is idle, on the average, more than half the time. By interlacing two conversations to take advantage of these gaps, it should be possible to make better use of existing transmission facilities. In practice, such a system would not work with only two speakers on the line, since they would frequently be talking at the same time. However, where a larger number of channels is available, such as in a submarine telephone cable, an averaging effect occurs, so that at any instant there is a greater probability of sufficient " free time " being available to accommodate the larger number of conversations. When there are more speakers than channels, the equipment now

Greater V-Belt reliability means more productivity

YOU CAN'T RISK costly shutdowns on full-scale production jobs – that's why Goodyear belts are the wisest choice for Multi-Vee drives. They can be fitted and forgotten – there's no better testimony to their trouble-free operation! There's a range of these 'job-designed' Goodyear V-Belts to give longer service and more efficient transmission on every type of drive. The Goodyear Technical Man will gladly advise on the right belt for any job.

E.C.V.



BELTS FOR MULTI-VEE DRIVES

- Withstand high starting torques, sudden shocks and pulsating loads.
- Minimum stretch and creep.
- Tough rubber-impregnated fabric preserves the belt section, resists side-wear and gives positive grip.

GOODYEAR

INDUSTRIAL RUBBER PRODUCTS

CONVEYOR BELTING · V-BELTS · TRANSMISSION BELTING · HOSE

being developed will connect active speakers and disconnect speakers who are silent at that particular moment. In turn, this disconnected speaker will be assigned another momentarily inactive channel when he resumes talking. A speaker will be disconnected only when he is silent; when he starts speaking, his voice actuates one of a number of speech detectors, which are scanned by a control circuit similar to a digital computer. When a speaker becomes " active ", this control circuit initiates a coded tone-burst, consisting of a group of four audio tones which precede the voice over an available cable channel. After the tone-burst, the control circuit connects the speaker to the same channel. The coded tones operate switches to connect the speaker to the proper line at the receiving end.

• *MAGNETICALLY CONTROLLED SWITCHING ELEMENT UTILIZING SUPERCONDUCTIVITY*

A recently patented magnetically controlled switching element utilizes the phenomenon of superconductivity to control current flow by creating and destroying the conditions necessary for superconductivity. It is also possible to provide a bi-stable circuit employing two interconnected switching elements, and also a coincident-current switching element which may, if desired, be used in conjunction with the bi-stable circuit to produce a coincident-current memory circuit. Basically, the equipment consists of an array of switching elements, made up of a number of conductors with critical temperature and magnetic-field transition characteristics between the superconductive and resistive states, the switching effect of these elements being produced by applying a magnetic field which destroys the superconductivity of the conductors, when required. An advantage of this design is that it operates at very low impedance and power levels and provides power gain ; furthermore, it provides current gain, as a relatively small current can control a large current. If required, the elements may be interconnected to provide logical circuits forming complete computing devices. Tantalum is one material which is superconductive in a helium bath at atmospheric pressure, and its use as the conductor of the switching element is recommended. When a magnetic field is created around a tantalum conductor at 4·2°K and the field is then gradually increased, the temperature at which the tantalum becomes superconductive decreases, and, at about 50 gauss in liquid helium at 4·2°K, the transition to ordinary resistive conductivity takes place. Where tantalum is used as the conductor, such materials as niobium or lead can be utilized for the control winding, niobium being preferred, as it is strong and is not influenced by the presence of fields below about 2000 gauss at a temperature of approximately 4·2°K. A typical switching element consists of a tantalum wire, 0·1 in. in diameter and 1 in. in length, around which is wound a tight coil (250 turns per inch) of insulated niobium wire, 0·03 in. in diameter. With this construction, a current of 300 mA in the niobium control winding will be sufficient to change the resistance of the tantalum wire from zero to 0·007 ohm per inch, with a current of 50 mA flowing through the tantalum wire.

• *NEW TYPES OF FOAMED SILICONES*

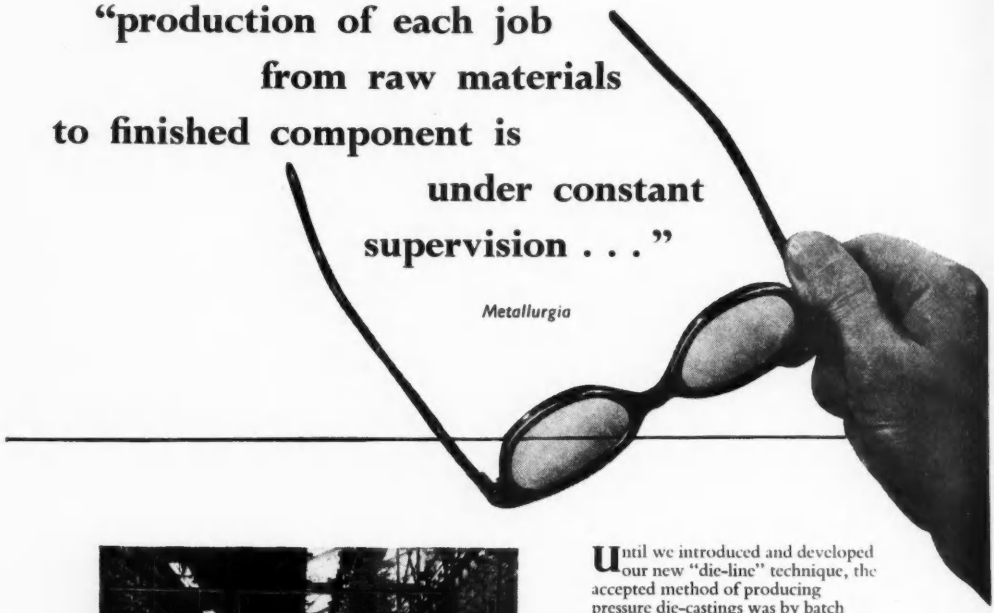
Information on new types of silicone foams for high-temperature insulation has just been released. Two such foams of the resin-base type are claimed to be stable at temperatures up to 650°F and capable of withstanding higher temperatures up to 700°F for limited periods. One of these is a rigid foam with a density of 4 to 5 lb/cu ft, while the other foam, of the same density, is semi-rigid and less brittle. The ingredients are a silicone resin and an additive, and, in order to obtain a uniform cell structure, the ingredients are blended with high-speed mixers. Foaming starts immediately after the mixing, and the material must be quickly cast into the mould or foamed in place. Expansion of the soft foam is complete in 15 min, but for maximum strength it should cure for 24 hr. The density of the foam is claimed to be uniform, material having been foamed up to 6 ft in height with only a slight density variation from top to bottom. When the cavity is too large for a single pour, successive batches can be cast on top of each other, allowing suitable intervals. Water absorption is said to be low, as these silicones are hydrophobic. However, only 40% of the cells are closed and the foams are therefore not completely moisture-resistant. Although they retain their flexibility to —65°F, they are unsuitable for insulating at low temperatures as their pore structure will eventually soak up moisture, resulting in an increase in their thermal conductivity and a decrease in their electrical resistance. Self-curing and self-expanding silicone rubbers have also been developed, and have foaming times which are much shorter than those of the resin foams, setting within 4 min. Moulded foamed parts acquire approximately 80% of their ultimate strength within 5 min, and their maximum continuous operating temperature is 400°F.

• *POST-HEAT TREATMENT OF WELDED PIPE-JOINTS WITH EXOTHERMIC MATERIAL*

A recent report describes the use of an exothermic material for the post-heat treatment of welded joints made on piping of low chromium-molybdenum material such as 5% Cr-0·5% Mo steel. This steel, when fabricated by welding with matching electrodes, develops a

"production of each job from raw materials to finished component is under constant supervision . . ."

Metallurgia



Until we introduced and developed our new "die-line" technique, the accepted method of producing pressure die-castings was by batch production. It involved handling, transit and storage between operations and the risk of damage to critical surfaces—particularly those intended for subsequent plating—was always present. It was uneconomical in floor space and made supervision difficult. All this has changed. The new die-line permits continuous production with all the finishing operations performed on a single conveyor line. Every operation is under constant supervision, and as no casting can touch another, impact damage has been eliminated. If you have a project where quantities are substantial these facilities are at your service and your enquiries would be welcomed.

THE WOLVERHAMPTON DIE CASTING CO. LTD.

GRAISELEY HILL WORKS,
WOLVERHAMPTON.
Tel: 23831/6.

high as-welded hardness in the weld and heat-affected zones. Consequently, post-heat treatment is usually required to transform the hard as-welded structure to one possessing more suitable engineering properties. Post-heat treatment on site is generally effected by electric resistance or induction methods and, when properly applied, has proved satisfactory. However, these methods are frequently costly, require considerable time to treat a joint, and are limited in the number of joints that can be heat-treated simultaneously. An exothermic material which could be applied to any number of joints simultaneously and would be economical in cost would have considerable application. The exothermic material chosen, which consists primarily of aluminium powder, metal oxides, refractory materials, and binders, is used in the shape of preformed half-cylinders designed to fit the outside diameter of the pipe joint. The material resembles a ceramic, and is baked in an oven to give it structural strength. When ignited with an oxyacetylene torch, the material burns with a delayed exothermic reaction and, although its active constituents are consumed, it retains its original shape. The half-cylinders of the material are placed over the weld, and insulation is placed adjacent to and on both ends of the material. The material is then covered with a high-temperature insulation, over which a layer of asbestos fibre is placed. After the heat-treating cycle, the assembly is left to cool to ambient temperature.

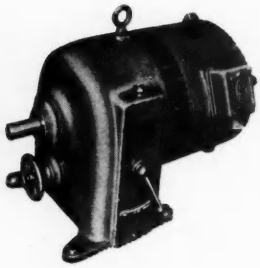
• *METHOD OF IRRADIATING PLASTICS WITH ELECTRONS*

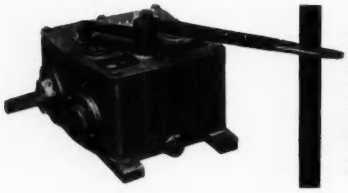
The irradiation of plastics with gamma-rays, X-rays, neutrons, and electrons for the purpose of influencing their molecular structure has recently acquired increasing importance. The most suitable method of irradiation is by means of electrons, e.g., by using an electron source in a high-vacuum vessel with a Lenard window provided in the path of the rays emanating from the source. This method has, however, certain fundamental disadvantages which can be overcome by using a recently patented method of irradiation, in which plastic material, in the form of strips or shaped pieces, is passed continuously through a high-vacuum vessel containing an electron source of irradiation. Admittedly, this process can give rise to considerable difficulties, particularly in connection with the evolution of gas from the plastic, so much so that, with large irradiation doses, the evolution of gas is sufficiently high as to make it appear impossible at first sight to be able to extract the gas by suction. However, it is now claimed that investigations have shown that, when irradiation is effected in a vacuum, such high energies are converted that difficulties caused by evolved gases can be avoided to a certain extent. Since the emission of gas takes place mainly by diffusion, and therefore gradually, it is proposed to make the period of irradiation as short as possible and to employ high irradiation energies. Thus, the material can be removed rapidly from the vacuum vessel, increasing the speed of treatment. In this way, the main quantity of gas evolved escapes from the plastic only in the free atmosphere or in a protective chamber. It may be assumed that only the outermost surface layers of the plastic contribute to the momentary emission of gas in the vacuum chamber. The gas thus formed can be removed from the high-vacuum chamber by a pump of sufficiently high output, e.g., 20,000 litres per second at 10^{-4} mm Hg.

• *GRAIN-BOUNDARY TRANSISTORS*

A new type of transistor, still in the laboratory stage, is reported to be capable of operating at cryogenic temperatures as low as 2°K, so that it should be useful for applications in space electronics, where low temperatures might immobilize the carriers in conventional semiconductor devices. The new device is called a grain-boundary transistor, because it utilizes the properties exhibited by the boundary formed between the crystal-lattice structures of different grain orientation to form structures similar to *n-p-n* or *p-n-p* junctions. If two seed crystals are tilted symmetrically about an axis, a bicrystal ingot can be grown naturally in which the two portions of the bulk material have lattice structures oriented at the third angle. The transistor is fabricated from slices cut from the ingot perpendicular to the growth direction. If the bulk material used is *n*-type germanium, the grain boundary exhibits *p*-type characteristics. Similarly, if *n*-type silicon is used in the bicrystal, the grain boundary is of the *p*-type. Analysis of the properties of the grain-boundary region is stated to indicate that a sheet of negative charges, caused by electrons captured in boundary states, is formed within the crystal, the negative charges along the boundary being compensated by a positive space charge composed of ionized donors (in *n*-type germanium). Consequently, the potential change across the boundary is similar to that of an *n-p-n* structure. This grain boundary exhibits two important characteristics, i.e., the independence of the grain-boundary sheet conductance with respect to impurity concentration, and the consequent temperature independence of the sheet conductance. Another interesting characteristic of the grain boundary is a photovoltaic effect, in which the photovoltage produced by a small light beam symmetrically distributed across the boundary experiences a polarity reversal which goes through zero.

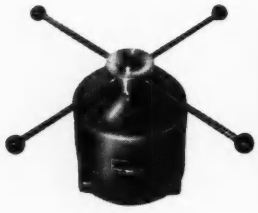
MULTIPLE SPEED GEARBOXES with co-axial shafts, capacities 5, 15, 35 H.P. overall ratios from 1-1 up to 7-1. Two, three or four speeds. Motorised or non-motorised.





VARATIO POSITIVE VARIABLE SPEED GEARS for speed changing under power. Capacities up to 45 H.P. Overall ratios, standard 2-1, 3-1, 4-1, in 7, 9, 13 speeds respectively. Spur gear, co-axial drives.

"STRATELINE" SPEED-REDUCER. Horizontal foot-mounted, universal flange-mounted. Single, double or triple stage. Motorised or non-motorised. Co-axial shafts. Ratios up to 10,000 to 1. Output TORQUE up to 64,000 lb. in.



VALVE AND WINCH OPERATING GEAR Co-axial shafts Flange-mounting. Developed for individual applications. Hand or power operation.

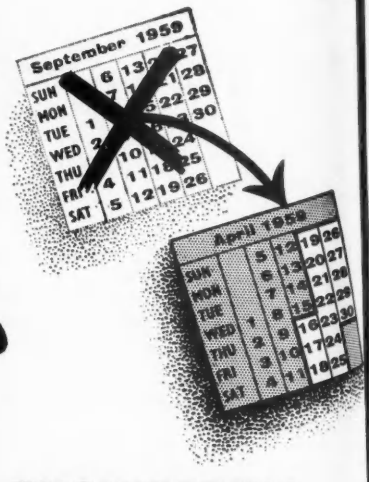
above **are typical examples from our range of variable speed gear units and speed reducers. Special units developed to customers' requirements.**

Write for further details.

VARATIO-STRATELINE GEARS LTD

277-279 Aberdeen Ave., Trading Estate, Slough, Bucks.
Telephone : Slough 20271/2. Telegrams : Varatio, Slough.

A Popular Change of Date



ENGINEERING marine welding & nuclear energy EXHIBITION

The largest event of its kind in the world

If you are an Engineer—of whatever kind—this is YOUR Exhibition. In Olympia on a floor space of over a quarter of a million square feet, over 500 of the world's leading manufacturers will show their most up-to-date equipment for your benefit. This Exhibition has been internationally famous for over 50 years. It occurs only once every two years. Previously it has been held in September, but in 1959 for the first time it has been possible to meet the popular demand for the Exhibition to be staged in the Spring of the year.

OLYMPIA - LONDON
APRIL 16th-30th, 1959

Opening hours : April 27th, 28th, 29th—10 a.m. to 8 p.m.
ALL OTHER DAYS—10 a.m. to 6 p.m. CLOSED SUNDAYS

Organised by
F. W. BRIDGES & SONS LTD.
Grand Buildings, Trafalgar Square, London, W.C.2
Tel: Whitehall 0568, 5 lines.

• *DIFFUSION METHOD OF PRODUCING PURE HELIUM*

A new diffusion method which should greatly increase helium production is stated to be capable of producing helium containing only 0·0009% hydrogen. This new production technique is of particular importance, since the demand for helium has risen much faster than the ability to produce it, and also because most present supplies of helium are mixtures with other gases. The diffusion technique used greatly simplifies the extraction of helium and depends on the fact that silica glass has an extremely high permeability for helium, i.e., about 1000 times as high as for hydrogen, and this permeability is high enough to make the method practical for large quantities of gas. In order to make the method commercially feasible, a large surface of the glass must be exposed, glass thickness must be small, and it must be possible to maintain a large pressure differential between the two sides of the glass. These requirements are met by the use of bundles of fine glass capillary tubing, arranged so that the gas under high pressure flows over the outer surface of the tubing, the helium being recovered from the bore of the tubing. It is stated that these tube bundles are so strong and wear-resistant that they can be placed directly in pipelines connected to the helium source. Capillary tubing with an outside diameter of 0·002 in. and a wall thickness of 0·0002 in. is used, and is capable of withstanding pressures up to 1000 atm and temperatures up to 400°C. This high strength at elevated temperature is important, since the diffusion rate of the gas rises sharply at high temperatures, being 100 times greater at 400°C than at room temperature.

• *RUBIDIUM-VAPOUR MAGNETOMETER*

A simple compact magnetometer having considerable advantages over previous instruments of this kind has been developed and is capable of measuring extremely small magnetic fields with great accuracy by locating very narrow Zeeman absorption lines in rubidium vapour. The high sensitivity, stability, and potentially small size of this rubidium-vapour magnetometer make it particularly well-suited for use in rockets and satellites. The instrument makes use of the fact that the absorption of polarized light in rubidium vapour depends on the orientation of the rubidium atoms. When circularly polarized light of a particular wavelength is passed through rubidium vapour, atoms are " pumped " out of orientations where absorption is high. The final result is " optical pumping " from high-absorption to low-absorption orientation, as atoms returning from the excited state tend to accumulate in the lower absorption orientations. In a radio-frequency field, rubidium vapour displays absorption lines at its Zeeman transition frequencies, i.e., the frequencies into which a normal emission line is split by a magnetic field. As the Zeeman transitions correspond to changes in atomic orientation, their frequencies can be determined by observing changes in the absorption of polarized light in the vapour. Since the magnetic field is related to the transition frequencies by accurately known constants, precise measurements of magnetic fields can conveniently be made. The magnetometer consists of an absorption cell containing rubidium vapour and a buffer gas, a rubidium lamp, the output of which is circularly polarized, and a quarter-wave plate. The amount of light transmitted is monitored by a photocell. A radio-frequency field is applied at right-angles to the field to be measured, causing the atoms to change their orientations. This frequency is varied and, when the transition frequencies are reached, light is absorbed in a greater amount than when the atoms are aligned.

• *PRODUCTION OF HIGH-TEMPERATURE REACTIONS WITH A ROTATING ARC*

It is known that many chemical reactions could be commercially utilized if sufficient heat could be provided to activate the compounds by heating to temperatures between 1000 and 4000°C. As the temperature produced by a high-density arc has been estimated to be above 4000°C, it would appear to be suitable for the purpose. However, this temperature prevails only in the core of the arc and falls off very rapidly from the core, so that it is difficult to heat a gas homogeneously with an arc, as it is essential that all the gas molecules contact the narrow core of the arc. It is true that it is possible to increase the core volume of an arc by lengthening the arc, but this method is not very satisfactory for continuous operation, owing to high voltage requirements, to difficulties in controlling the arc, and to its instability. Now, however, these difficulties are stated to be overcome by a new process in which use is made of a continuously rotating arc. In this process, the reactants to be heated in a gaseous state are passed through a symmetrical annular gap formed by a cylindrical solid electrode and a cylindrical hollow electrode, the arc between the electrodes being rotated by a magnetic field. The contact of the gaseous material with the arc in rapid rotation is stated to result in a surprisingly uniform heating of the gaseous material to temperatures as high as 4000°C in very short contact times. It is also stated that a rotating arc has a surprisingly greater stability than a linear arc. For most purposes, carbon or graphite electrodes can be employed, feeding of the gas or its removal being effected through the bore of the hollow electrode.

Wherever power is used Crofts Gearboxes play a vital role . . .

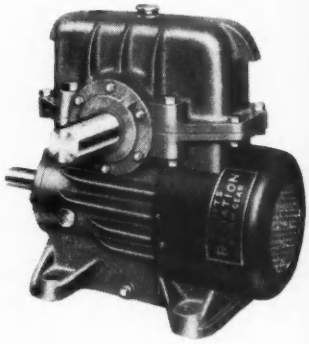
CROFTS "RADIATION" WORM REDUCTION GEARS

Fractional to 400 h.p.—Ratios up to 100:1

Publications 521, 522, 523, and 524

3" to 14" centres, up to 135 h.p. from Stock—

—phone Ext. 555



- A highly efficient, rugged speed reducer
- Rib or fan cooled
- Can also be had inverted (worm over wormwheel) or vertical (wormshaft horizontal, wheelshaft vertical)

CROFTS ALSO MAKE:

Clutches, Conveyor drives, Couplings of all types, Double helical gear units, Fabricated steelwork, Geared motors, Hydraulic couplings, Iron, Steel and non-ferrous castings, Machine-cut gears of all types, Motorised Rollers, Patent taper-Flushbushes, Plummer blocks, Shaft-mounted gear units, Special machinery drives, Spiral bevel gear units, Turbine gears, V-rope Drives, Variable speed drives, Worm reduction gears.

CROFTS (ENGINEERS) LIMITED

POWER TRANSMISSION ENGINEERS

BRADFORD 3 YORKSHIRE

Telephone: 65251 (20 lines) Telegrams: 'Crofters Bradford Telex' Telex 51186

BRANCHES AT:

Belfast Birmingham Bristol Cardiff Dublin Glasgow Ipswich Leeds Liverpool London Manchester Newcastle Northampton Nottingham Sheffield Stoke-on-Trent

Representation throughout the world

THE ENGINEERS' DIGEST
REVIEW OF WORLD ENGINEERING PROGRESS
VOL. XX No. 3 MARCH, 1959

Visco-Elasticity in Lubrication

By G. J. O'DONNELL. (From *Mechanical Engineering, U.S.A.*, Vol. 81, No. 2, February 1959, pp. 63–65.)

THERE are several basic deficiencies in our understanding of lubrication phenomena, especially in high-speed performance. For example, among the many anomalies is the performance of spur gears at high speeds, characterized by decreasing load-carrying capacity with increasing speed up to a critical speed, and then increased load-carrying capacity with increasing speed. Under these high loads it has been shown that plastic flow can take place on spur-gear teeth. Pressures as high as 5×10^5 psi obtain, yet radioactive studies on gear teeth have shown that lubricants can prevent metal-to-metal contact, even under such conditions.

With regard to the actual definition of visco-elasticity, it should be noted that, in 1867, Maxwell predicted from a theoretical model of the liquid state that, if a liquid were stressed rapidly enough, it would show an elastic response to the stress. In other words, depending on the rate of application of a shear stress to a liquid, the shear response could be that of a normal viscous liquid or of an elastic solid. Thus, if it responded as a combination of both, it would be what is termed a visco-elastic substance.

Maxwell's prediction has by now been proved not only for liquids, but even for air, if the rate of stressing is high enough. In stressing a visco-elastic material, mechanical energy is partly stored in the form of potential energy in the substance and partly dissipated as heat. To metallurgists visco-elasticity is more familiarly known as creep.

Consider a material which will undergo an instantaneous elastic response when stressed, but which can also flow. The total deformation ε of such a material under shear stress is the sum of its elastic deformation and its flow. The elastic deformation is simply $(1/G)\sigma$, where G is the shear modulus and σ is the stress at time t. The flow deformation, however, depends not only on the stress, but also on the duration of the stress. Consequently, all that can be said is that the instantaneous rate of flow is given by $(1/\eta)\sigma$, where η is the viscosity. As a result, an explicit expression relating the deformation with the stress is not possible. It is, however, possible to derive an expression giving the rate of change of the deformation. Thus, from the above, for the elastic displacement,

$$\frac{d\varepsilon_1}{dt} = \frac{1}{G}\frac{d\sigma}{dt} \quad .. \quad .. \quad (1)$$

and, for the flow displacement,

$$\frac{d\varepsilon_2}{dt} = \frac{1}{\eta}\sigma \quad .. \quad .. \quad (2)$$

Consequently, for the total displacement $\varepsilon = \varepsilon_1 + \varepsilon_2$,

$$\frac{d\varepsilon}{dt} = \frac{1}{G}\frac{d\sigma}{dt} + \frac{1}{\eta}\sigma \quad .. \quad .. \quad (3)$$

This merely states that the total rate of change of the displacement is given by the rate of flow plus the rate of change of the elastic part of the deformation, and is the fundamental differential equation which governs the mechanical response of the material, not only to a constant shear stress but also to any sequence of shear stresses and of constraints on the deformation itself.

The behaviour of a material exhibiting flow superimposed on elasticity can be represented by the mechanical analogue of a spring and dashpot in series. It can just as well be represented by creep functions, mechanical impedance functions, operator equations, or rate equations. In the case of the spring and dashpot, when the stress is applied, the spring immediately stretches by the amount σ/G, and the dashpot elongates steadily at the rate σ/η. When the stress is removed, the spring instantaneously contracts, but the dashpot remains where it is.

The relative importance of these responses obviously depends not only on the magnitude of G and η, but also on the time scale of the experiment. If the stress acts for a time T, the magnitude of the elastic deformation is σ/G, and for the flow deformation $(\sigma/\eta)T$. If T is very small, compared with η/G, then the elastic deformation will completely overshadow the flow, and the material can be considered an elastic body. If T is very large, compared with η/G, the flow will overshadow the elastic response, and the material would be considered as a simple Newtonian fluid. Only if T is of the same order of magnitude as η/G is the composite nature of the deformation apparent.

For real materials, which exhibit a whole spectrum of relaxation times, a single Maxwell model of a spring and dashpot in series will not suffice. For these, it is necessary to use an entire series of them, arranged in parallel.

In considering molecular behaviour and the mechanisms that can be assigned to springs and dashpots, it should be appreciated that existing molecular theories are so crude that they give a very qualitative and tentative mechanistic interpretation to the elements of the model. In some cases, however, it is possible to relate the relaxation time to the chemical kinetics of a definite, specified chemical reaction.

As a general example, consider the shearing of an oil solution of polymer molecules. There are many different kinds of forces holding molecules together, and each of these affinities has different rates of breaking and reforming. Consequently, there is a distribution of relaxation times. To the spring elements can be assigned the stretching of primary valence bonds; pulling chains away from neighbours; opening up valence angles; straightening out kinks, curls, convolutions, and entanglements of the polymer molecules; and twisting bonds against the hindering potential which interferes with free rotation. All these store energy, so to it must be added

the decrease in entropy when shearing restricts the polymer chains to less probable configurations. To the dissipative function, or dashpot, can be ascribed such irreversible reactions as breaking chemical bonds, van der Waals' bonds, dipole-dipole interactions, hydrogen bonds, and labile covalent bonds; slippage of polymer chains past one another; and the other factors which go to make up the normal viscosity of the oil itself.

With regard to eq. (3), it should be pointed out that this equation applies only to a linear system with one degree of freedom. Furthermore, η is a function of the shear rate for non-Newtonian fluids, and typical visco-elastic fluids are all non-Newtonian. This, in turn, will affect the relaxation times. Consequently, data are needed on the properties of oils under high rates of shear, their relaxation times, etc. Though such data are available for many polymers, little is known about oil *per se*.

If, in the case of a spur-gear machine, the oil has a relaxation time of the same order of magnitude as the contact time, it can be seen that the lubricant will act as an elastic solid and hence will carry a load much greater than that predicted from hydrodynamic theory. In other words, the oil would act like a spring, instead of flowing out from between the gear teeth. It would also explain the increase in load-carrying ability at increasing speeds, if these speeds yielded shear rates of the same order of magnitude as the relaxation times.

The time scale involved in the high-speed operation of ball bearings, as well as spur-gear machines, can be of the order of 10^{-6} sec. Little data are available on the relaxation times of mineral oils, silicones, diesters, or other fluids of about 1-poise viscosity, although theory predicts that these times are of the order of 10^{-6} to 10^{-8} sec. Increasing pressure of temperature could change this, but would increase the difficulty of measurement.

Up to this point, discussion has been limited only to a single stress and its associated displacement. However, in most applications, several stresses are involved. As it happens, these mainly produce cross stresses and cross viscosities which can best be handled by the non-linear mechanics of Reiner.

In this connection, some mention should be made of what is meant by linear and non-linear theory. Materials which obey linear theory are such that two stresses applied simultaneously produce the same effect as the same two stresses applied consecutively. For example, a material for which the linear theory is adequate will be deformed in the same manner if it is sheared and compressed simultaneously, or if it is first sheared and then compressed. On the other hand, for materials which require the application of a non-linear theory, the result will depend on the order in which the operations are carried out. Thus, a material conforming to non-linear mechanics will generally expand, if sheared without the simultaneous application of a compressive force.

The non-linear theory is required for treatment of any material, whether fluid or solid, where internal forces arise in response to a strain. Although Reiner has shown that these cross stresses arise even in materials showing bulk elasticity, they are of a larger order of magnitude in materials showing shear elasticity. A familiar example of behaviour explained by non-linear theory is that of twisting a rod. It had been long known experimentally that, on twisting an elastic rod slightly, it will elongate proportionally to the square of the angle of twist. Swift, for example, has shown that, in plastic torsion, rods made of steel or copper lengthen, whereas those of lead shorten.

Another illustration of cross terms dealt with by non-linear theory may arise when a fluid is rotated about a fixed rod. With a primarily Newtonian fluid, the centrifugal action forces the liquid against the outer walls of the container. With a visco-elastic material, however, the fluid will climb up the rod, and the force required to prevent such a rise is proportional to the square of the rate of rotation. In climbing rotating shafts, these visco-elastic fluids are displaying the force normal to the direction of shear required by the non-linear theory. This particular effect is called the Weissenberg effect.

When considering how some of these properties inherent in a visco-elastic lubricant may affect the load-carrying capacity of a very-high-speed, heavily loaded journal bearing, it will be appreciated that the lubricant is circulated by the rotation of the bearing and can be periodically subjected to very high rates of shear as it passes through the narrowest clearance. The viscosity of most visco-elastic materials decreases with increasing shear rates. In addition, there may be some permanent lowering of the viscosity of the fluid, because of degradation caused by shear and/or cavitation. Inasmuch as the load-carrying capacity of a journal bearing is, according to hydrodynamic theory, determined by the viscosity of the fluid, these factors tend to lower the capacity. During the rotation of the bearing, the fluid carried through the narrow region is subjected to a periodic stressing. If this period is of the same order of magnitude or less than the relaxation time, the load-carrying capacity should be increased, since the lubricant will act like an elastic solid. Similarly, the normal force, or Weissenberg effect, increases at high rates of shear, and it should therefore also increase the capacity.

The experimental problems associated with the determination of relaxation times are considerable. At atmospheric pressure and ambient temperature, the relaxation times will generally be less than a microsecond. This, in turn, means that the experimental equipment designed to measure relaxation phenomena must operate near the megacycle region, involving complicated techniques, Furthermore, extremely high temperatures and pressures are frequently involved in actual lubricating processes. These, in turn, can change the viscosity and the shear modulus and hence the relaxation times. Considering the temperatures and pressures involved, it is apparent that the experimental difficulties are compounded.

Before any attempt can be made to consider the phenomenon of visco-elasticity in the design of high-speed machines, not only is it necessary to know the viscosities and relaxation times at high temperatures, high pressures, and very high rates of shear, but it is also essential to know how these factors influence both boundary and hydrodynamic friction. Inasmuch as this represents an inordinate expenditure of effort, a few preliminary experiments are required. Thus, a few polymeric solutions should be examined, in order to find some with a relaxation time of the order of magnitude. germane to the stress periods experienced in machines. Furthermore, in order to ensure that the visco-elastic properties will not be lost in actual operation involving high rates of shear, one must be selected with minimum viscosity-shear sensitivity. Then, and only then, can engineering experiments be designed to see to what extent visco-elasticity can be a contributory factor in the performance of machine elements.

If it is established that visco-elasticity plays an important role in lubrication, then the acquisition of large amounts of basic data is not only justified, but is practically imperative.

High-Productivity Milling Cutters

By O. Ya. Konstantinov. (From *Mashinostroitel, Russia*, No. 1, January 1959, pp. 37–40, 6 illustrations.)

In order to increase efficiency and to reduce the costs of milling operations, great attention is being paid in Russia to the application of new high-speed tools and to increasing the strength and resistance to vibration of milling cutters. A smaller number of teeth, an enlarged flute area, and steeper helix angles are some of the design features favoured in Russia.

As an example, in the end-milling cutter illustrated in Fig. 1, the number of teeth has been greatly reduced, making it possible to enlarge the area of the flutes and to increase the strength and wear resistance of the individual teeth. Generally, this type of cutter is designed with 3, 4, or 5 teeth, depending on cutter diameter. The conventional straight-line contour of the flutes is replaced by a profile made up of arcs with radii of 4 to 5 mm, the helix angle being 35 to 45 deg. This flute contour, combined with the relatively steep helix angle, is claimed to facilitate chip removal and to eliminate clogging entirely. Furthermore, owing to the larger feeds permitted, every tooth can deal with an increased volume of chips and, at the same time, the pressure on the teeth and power consumption are considerably reduced.

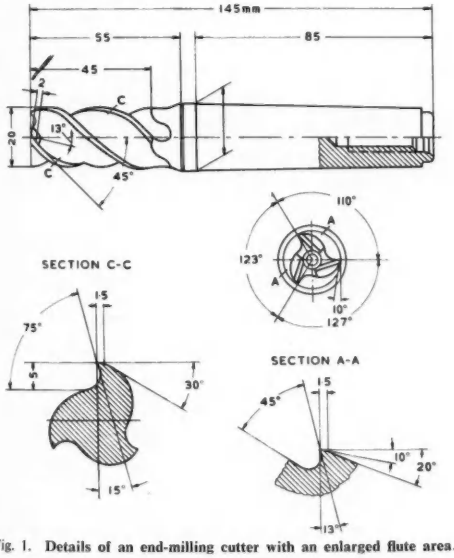


Fig. 1. **Details of an end-milling cutter with an enlarged flute area.**

To lessen the effects of vibration on the tool, particularly under heavy loads, the teeth are unequally spaced, the pitch of the teeth of the cutter shown in Fig. 1 being 110, 123, and 127 deg., while, for a milling cutter with five teeth, the recommended successive angles are 68, 72, 76, 68, and 76 deg. Because of the unequal spacing, every tooth starts its cutting action at a different instant and removes chips of different cross-section, the chips produced by this cutter being greatly deformed and breaking off easily during metal removal.

The slotting cutter shown in Fig. 2 differs from other cutters of conventional design by using a smaller number of teeth, larger flutes, and facets on each tooth, the width of these facets, which are located on alternate faces, being about one-third of the cutter width. During the machining of a steel workpiece with this type of cutter, speeds of 30 to 50 m/min and feeds of 150 to 300 mm/min were obtained, as compared with a standard slotting cutter, which gave speeds of 20 to 30 m/min and feeds of 30 to 50 mm/min on the same workpiece.

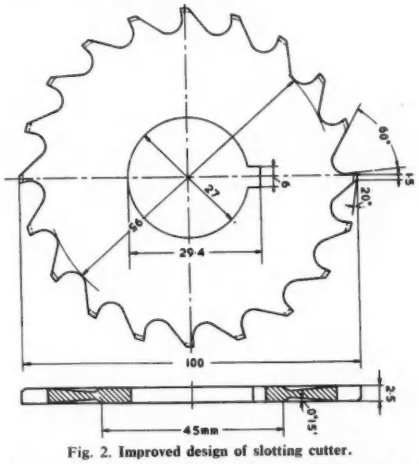


Fig. 2. **Improved design of slotting cutter.**

Of particular interest are improvements introduced in connection with special end-milling cutters used in mass-production for cutting slots and grooves of 20 to 100 mm in depth. These cutters have equally spaced teeth and special spiral-shaped flutes, with a pitch of 10 mm, for improved chip-breaking. In the preliminary versions of these cutters, the small helix angle of the flutes led to clogging, and consequently to overheating of the cutting zone and to a reduction in the hardness of the cutting edges. As a result, this particular design proved unsuitable for high-speed cutting.

To overcome these defects, an improved version of

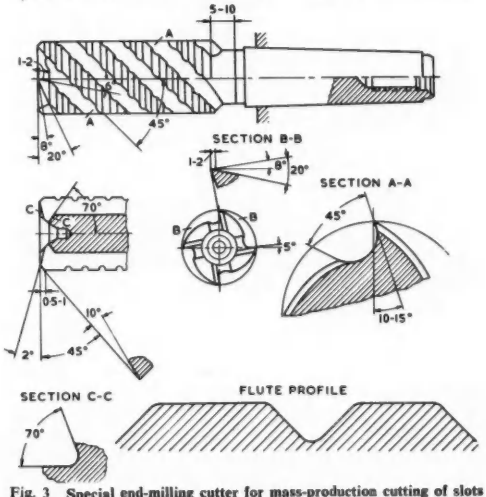


Fig. 3. **Special end-milling cutter for mass-production cutting of slots and grooves.**

this type of cutter has been developed (Fig. 3), using a smaller number of teeth, a steeper helix angle, and a different flute profile. The backs of the teeth are polished, in order to eliminate the possibility of rubbing, with the consequent generation of excessive friction, which would impair the quality of machining. In this design, the helix angle has been increased to 45 deg., and a land, 1 to 2 mm in depth and inclined at an angle of 6 deg., is cut on each tooth. The beginning of the flutes is set back by one full pitch, i.e., 10 mm, from the cutting edges.

With these special flutes, the chips are relatively small and are much narrower than the full cutting width. The actual width b of the chips can be calculated from

$$b = B - ak$$

where B = total cutting width [mm], a = width of the flutes [mm], and k = number of flutes in a width B.

During machining with this type of cutter, the chips are subjected to large and complex deformations which could consume excessive power and generate high temperatures. To overcome this possibility, the flutes are made as large as possible; for example, for a cutter of 50 mm in diameter, a root radius of 7 mm is used, accommodating a large volume of chips without causing substantial deformations during metal removal.

The first applications of this improved end-milling cutter have shown great savings in time and power. In comparative tests of this cutter and a conventional cutter, the power consumed was decreased by a factor of 1·46, speed was increased from 18·5 to 23·5 m/min, and feed was increased from 30 to 75 mm/min. When cutting a groove of 50 mm in width and 30 mm in depth in a steel workpiece, a speed of 30 m/min and a feed of 375 mm/min were recorded. As a result of the success of these experiments, it is intended to mass-produce this tool in Russia in the near future.

U. S. A.

Phase-Contrast Techniques in Metallurgical Microscopy

By G. Koves. (From *IBM Journal of Research and Development*, Vol. 3, No. 1, January 1959, pp. 85–92, 9 illustrations.)

The primary function of heat treatment is to change certain properties of metals and alloys favourably by altering the crystal and grain structures. Precise determination of the internal structure is an important guide for the control of the various treatments, and in this respect metallographic examination is a valuable tool.

The exact determination of the constituents in the structure of a case or core is important in controlling heat-treating operations and maintaining required close tolerances and properties. The commonly used microscopic methods, however, are not always adequate for differentiating closely related microconstituents such as cubic martensite and lower bainite, or upper bainite and fine pearlite. These microconstituents frequently cause undesirable effects, e.g., uneven or generally poor wear resistance, low impact strength, and premature fatigue failure.

Phase-contrast microscopy is a newly added feature in modern metallography and has proved useful in identifying some microconstituents of inhomogeneous areas in case-hardened steel components. This article presents a summary of the method and characteristic problems solved with the aid of phase-contrast microscopy. It should be noted that the application to opaque specimens is discussed, whereas most literature on the phase-contrast method concerns transparent specimens.

Although the various microconstituents in steel are quite well known and understood by metallurgists, there is still a number of different opinions and theories about the so-called "intermediate transformation structures." X-ray diffraction is the proper tool for precise determination of crystal structures, but its applications are limited and the method is too time-consuming for practical use in a production laboratory. The conventional metallographic microscope continues to be the most adequate general instrument for examination of heat-treated components. In conjunction with other equipment, such as a microhardness tester, it solves most problems. Its limitation, however, is that it merely provides a highly magnified image for the human eye.

The polished and etched metallographic specimen has a definite surface pattern conforming to the grain structure, and this pattern changes the intensity of reflected light or promotes a selective reflection of certain wavelengths. Light reflected from a metallographic specimen may, however, suffer alteration in phase from small local vertical displacements between slightly different structural elements or from variances of surface optical activity. This does not contribute to the efficiency of the examination, as the human eye cannot distinguish between light rays differing in phase. The phase-contrast microscope senses the small differences in phase and transforms them into observable modulations of light intensity. Structural details that otherwise would be unobserved may thus be seen.

Ordinary metallographic microscopes create the final image with the undeviated direct light reflected from the specimen and with all diffracted orders still collected by the objective. The diffracted light, recombined with the undeviated light, produces a modulation of light intensity which resembles the specimen structure. The phase-contrast microscope makes observable the phase differences of diffracted orders, thus improving the contrast of the final image.

In the phase-contrast metallurgical microscope, the ordinary bright-field illumination is converted by the addition of an annular diaphragm, where the image of the light is formed. The annular diaphragm is thus imaged in the rear focal plane of the objective. The objective, in turn, will create displaced images of the annular diaphragm by the undeviated, directly reflected light and diffracted orders. When a phase-retarding plate, of the same size as the annular diaphragm, is inserted into the rear focal plane of the objective, either the undeviated light or the diffracted orders can be altered in phase with respect to the other. At the same time, a suitable material in the phase-retarding plate, such as an evaporated coating of Inconel or aluminium, reduces the intensity of the undeviated light and increases the intensity of the diffracted light.

No additional sample preparation is required for phase contrast beyond that necessary for bright-field

illumination. The photomicrographs reproduced in this article are of selected areas of different specimens and show a characteristic portion of inhomogeneous structure under a magnification of ×750, using a dry objective and a light-blue filter, comparing identical areas in each case under phase-contrast and under bright-field illumination. All specimens were polished mechanically and etched with 2% nitric acid alcoholic solution for approximately 5 sec.

Fig. 1a is a photomicrograph of part of a roller stud, using bright-field illumination, while Fig. 1b shows the same area, using phase contrast. The Knoop hardness of this area (measured with a 500-gm load) was 580 to 670, i.e., equivalent to a Rockwell *C* hardness of 52 to 57. The material was a steel with a nominal composition of 0·13% max. C, 0·70–1·00% Mn, 0·07–0·12% P, and 0·24–0·33% S.

In Fig. 1a, it can be seen that the structure is extremely heterogeneous and that microconstituents are not clearly visible. Some martensite needles can be identified, but the matrix structure can only be assumed to be bainite. Comparison of Figs. 1a and 1b indicates that phase-contrast illumination shows more martensite (indicated by arrows in Fig. 1b), and that the matrix structure is almost uniform and is identified as lower bainite. The different layers in the bainite matrix can be recognized as diffusionless transformation products of iron and precipitated carbide plates.

The photomicrographs in Fig. 2 of part of the core structure of a stud made from the same material as that in Fig. 1 are typical representations of a case where neither technique adequately reveals all structural details. The two methods, however, offer a perfect solution if considered together. In the conventional bright-field illumination (Fig. 2a), three microconstituents can easily be identified, i.e., (1) the lower bainite plates with typical triangular pattern in the centre section, (2) the free ferrite grains, and (3) the manganese sulphide inclusions. There is no clear indication of the matrix structure. The phase-contrast photomicrograph (Fig. 2b) also indicates the lower bainite plates, but does not show the correct amount of free ferrite. Nevertheless, it can be observed in this picture that the matrix structure is partly upper bainite (such as in the lower right-hand corner of the micrograph) and partly fine pearlite. This structure is responsible for the great deviations in hardness.

Fig. 3 shows part of the centre section of a gear tooth made of a steel containing 0·14–0·20% C, 1·00–1·30% Mn, 0·040% max. P, and 0·08–0·13% S. The Knoop hardness of the structure was 410 to 460, equivalent to a Rockwell *C* hardness of 41 to 45. This is an unusual example in which phase-contrast microscopy offers a complete answer to the question of microstructure, even without the support of conventional microscopy. Standard bright-field illumination (Fig. 3a) shows some bainite plates, but does not give a clear indication of the majority of the structure. The phase-contrast technique,

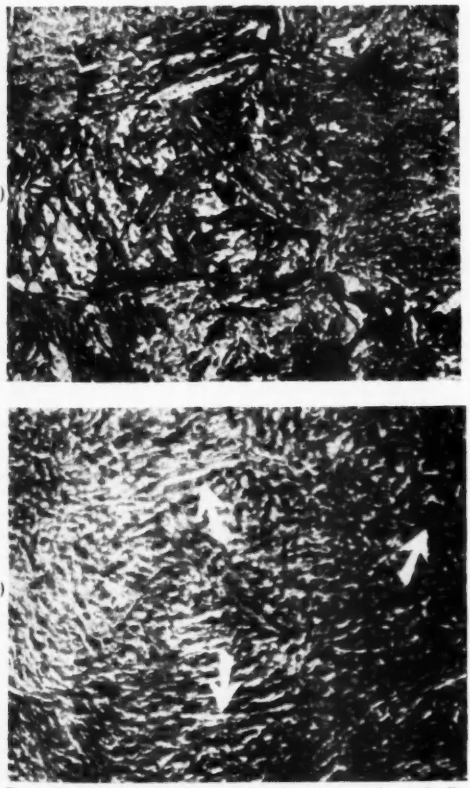


Fig. 1. **Photomicrographs of part of the microstructure of a steel roller stud, (a) under bright-field illumination, and (b) under phase-contrast illumination.** (×750)

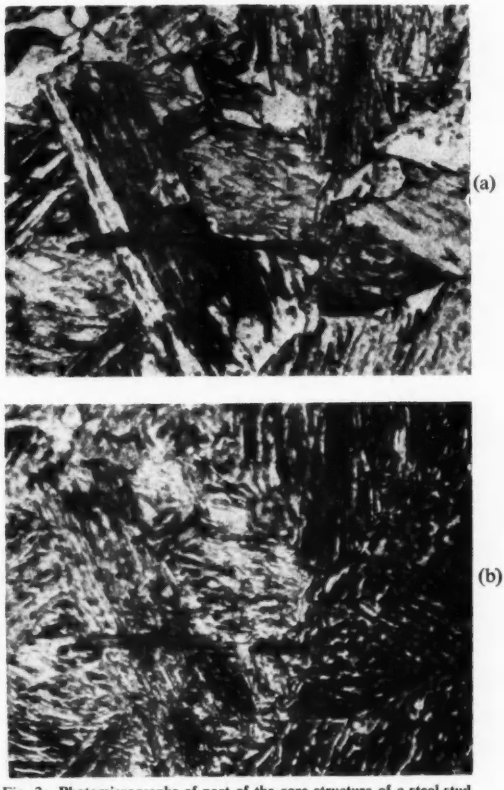


Fig. 2. **Photomicrographs of part of the core structure of a steel stud, (a) under bright-field illumination, and (b) under phase-contrast illumination.** (×750)

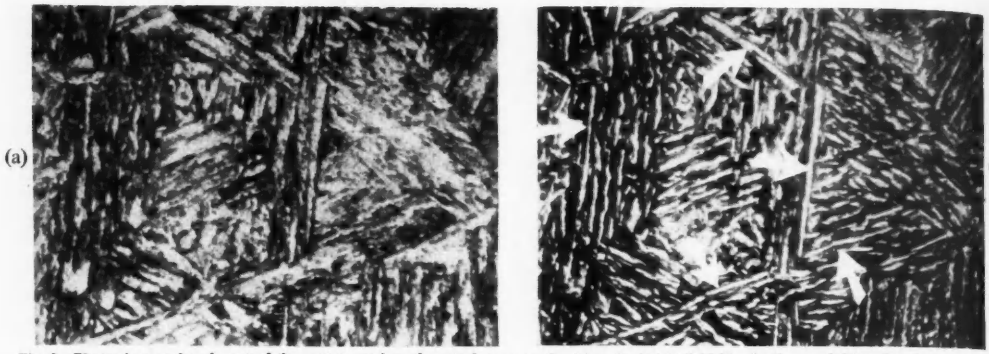


Fig. 3. Photomicrographs of part of the centre section of a steel gear tooth, (a) under bright-field illumination, and (b) under phase-contrast illumination. (×750)

however, as shown in Fig. 3b, supplies the answer and shows more details. The structure consists of two phases, i.e., lower bainite plates with the characteristic orientation (see arrows), and a matrix of upper bainite. Here, phase-contrast illumination not only reveals more detail, but actually presents a better and more complete interpretation of the microstructure than does the conventional technique.

Part of the centre portion of the core structure in the tenon of a stud made from the same steel as that in Figs. 1 and 2, but with a Knoop hardness of about 250, equivalent to a Rockwell *C* hardness of about 20, is shown in Fig. 4. Comparison of Figs. 4a and 4b reveals a characteristic property of the phase-contrast technique, important for proper representation of the structure. Fig. 4a shows areas of free ferrite on various parts of the section. These areas are not clearly seen in the phase-contrast photomicrograph (Fig. 4b), because of a substructure inside the ferrite grains. Nevertheless, the grain boundaries are definitely marked, and the substructure is different from the normal grain structure. The upper bainite plates and pearlitic matrix can more easily be identified in Fig. 4b, although complete understanding of the microstructure requires an examination with both conventional and phase-contrast techniques.

The phase-contrast method is as yet considered mainly as a technique in transparent-specimen microscopy, and as already stated, there is little in the literature on the application of this method to opaque-type specimens. Nevertheless, this technique can be used to advantage in cases where conventional microscopy does not give a complete explanation of structure and properties.

It must be emphasised that phase contrast is only a supplementary tool and should always be used in conjunction with the common bright-field illumination technique. There are cases (e.g., in Fig. 3) when phase contrast in itself seems able to supply a complete answer about the microstructure. In all other specimens examined, the phase-contrast method merely revealed more details in certain microconstituents or helped to clarify a confusing picture obtained by the conventional method. It should also be pointed out that there exists a frequent risk of misinterpretation when phase contrast is used as an independent examination method. One reason for this is that substructure appears in certain microconstituents with phase-contrast illumination (as in the case of Fig. 4). Another more general reason is that few comparative investigations have been made between conventional and phase-contrast methods, and the interpretation of a structure shown on the phase-contrast microscope is often uncertain.

More frequent utilization of this method in the future will provide more material and reveal new territories in which it can be used to advantage. The field of phase-contrast microscopy is restricted; it has considerable promise, however, when considered as an extension or supplement to current methods of microscopic evaluation of metals.

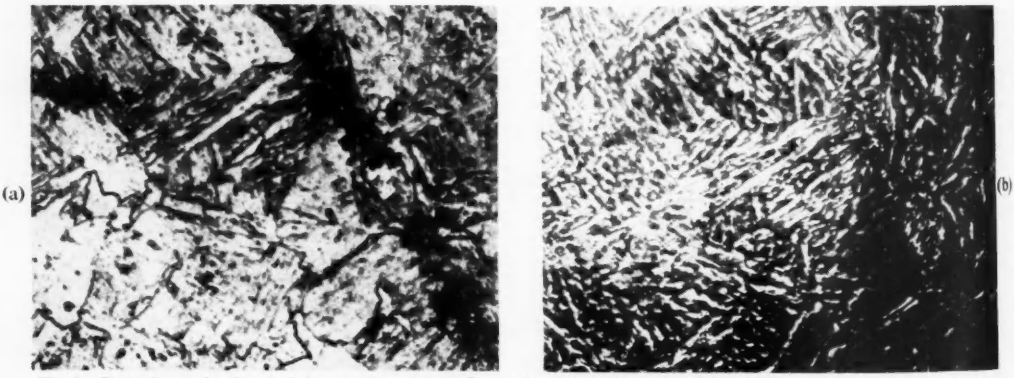


Fig. 4. Photomicrographs of part of the core structure in the tenon of a steel stud, (a) under bright-field illumination, and (b) under phase-contrast illumination. (×750)

Influence of the Peltier Effect in Resistance Welding

By. T. C. BALDER. (From *Philips Technical Review*, Vol. 20, No. 7, 1958/59, pp. 188–192, 10 illustrations)

DURING tests on a spot-welding machine for the fabrication of grids for radio valves, it was found that the direction of current flow had a marked influence on the strength of the weld. As shown in this article, this phenomenon can be explained by assuming it to be due to the Peltier effect.

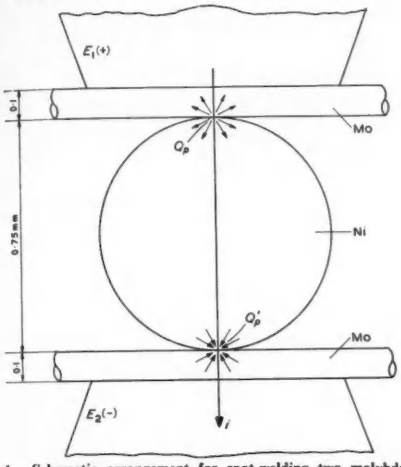


Fig. 1. **Schematic arrangement for spot-welding two molybdenum wires to a nickel wire.**

An arrangement for spot-welding two molybdenum wires simultaneously to a thicker crosswise nickel wire is shown schematically in Fig. 1. The welding current i is supplied to the copper electrodes E_1 and E_2 by the discharge of a capacitor through the primary coil of the welding transformer. Fig. 2 shows current i as a function of time t, with a peak value of approximately 860 A at about 0·35 millisecond. The current is effectively unidirectional and in Fig. 1 is assumed to flow from E_1 to E_2. Thus, in the upper weld, it flows from molybdenum to nickel, and in the lower weld from nickel to molybdenum. Now, in a thermocouple formed by nickel and molybdenum, the current i at the hot junction flows from Ni to Mo. The Peltier effect opposes this flow, i.e., it heats the cold junction and cools the hot junction. Thus, when a current passes through a Mo-Ni junction, heating occurs when the current direction is from Mo to Ni. Consequently, in the case of Fig. 1, in which the current i flows from the top electrode E_1 to the bottom electrode E_2, a quantity of Peltier heat Q_P is developed at the upper weld, while approximately the same quantity of heat Q_P' is absorbed at the lower weld. As a result, the upper weld has a higher temperature than the lower weld. In fact, it has been found that, when the current pulse is just high enough to weld the upper wire firmly, the lower weld is not yet properly consolidated. If the current pulse is raised sufficiently to weld the lower wire firmly, the upper wire usually melts through. If the direction of current flow is reversed, the same phenomena occur, but with the role of the upper and lower wires interchanged.

Although critical adjustment of the current pulse makes it possible to obtain satisfactory welds at both the upper and the lower stations, it takes only a few welds before surface contamination of the electrodes attenuates the pulse enough to prevent a good weld at the lower wire. When the electrodes have been cleaned, a number of good double welds can again be made.

In principle, the Peltier effect occurs whenever two dissimilar materials are joined by resistance welding. The fact that the effect is so unusually pronounced in the case described is partly attributable to its relatively high value at a Ni-Mo junction, but is mainly due to the fine gauge (0·1 mm) of the molybdenum wire used. With such fine wire a relatively slight rise in the heat developed at the welding zone tips the scales between non-adhesion and a melted-through wire.

In order to be able to predict whether or not the Peltier effect can be expected to influence a weld significantly, consider the Peltier power, i.e., the Peltier heat Q_P developed per second. This is proportional to the current i through the junction, so that

$$Q_P = Pi \quad .. \quad .. \quad (1),$$

where the proportionality factor P is the Peltier coefficient, which can be derived from the Thomson relation

$$P = T\frac{dV}{dT} \quad .. \quad .. \quad (2)$$

where T is the temperature of the junction [°K,] and V is the thermo-e.m.f. in a thermocouple of the two metals concerned, one junction of which is held at a constant temperature and the other has a temperature T.

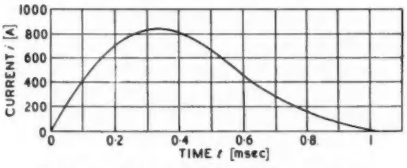


Fig. 2. **Welding-current pulse as a function of time.**

Values of dV/dT (the so-called thermo-electric power) can be found for arbitrary combinations of metals. Thus, for example, in the case of Fe-Mo, the values of dV/dT are appreciably smaller than for Ni-Mo. This implies that, if an iron wire were substituted for the nickel wire in Fig. 1, it should be easier to obtain good simultaneous welds of the upper and lower wires. Such is indeed found to be the case. Even with Fe-Mo, the Peltier effect still makes itself felt, for at a certain setting of the current pulse the upper wire is completely welded and the lower one is still loose. However, a slight increase in current is sufficient to weld both wires firmly. The weld cycle can then be repeated thousands of times without any need to clean the electrodes and without any tendency for the wires to melt through at one side or break away at the other.

The Peltier effect also probably explains why, in spot-welding, one electrode tip often deteriorates more rapidly than the other. Detailed investigations of this phenomenon have been made in connection with the spot-welding of magnesium-alloy sheet, and it has been found that, when welding with mainly unidirectional current pulses, the positive electrode suffers more than the negative electrode. Now, if the Peltier effect were responsible, it should in the case of Cu-Mg junctions give rise to additional heating of the positive electrode and to cooling of the negative electrode. As a check, measurements were made of the thermo-e.m.f. in a 98·5% Mg–

1·5% Mn alloy used in these investigations. The results showed that the positive electrode does indeed attain the higher temperature.

Energy Involved in the Peltier Effect

If a theoretical estimate is made of the energy released, or absorbed, in the form of Peltier heat during the welding process, this energy can then be compared with the total energy used for making a weld.

The Peltier heat is given by

$$\int i \times T \frac{dV}{dT} dt$$

The integration is carried out over the duration of the welding process. Fig. 2 gives current i as a function of time t. In Fig. 3, thermo-electric power dV/dT is plotted against temperature T for a nickel-molybdenum combination. In addition, the Peltier coefficient $P = T(dV/dT)$ is also plotted against T in Fig. 3. It is assumed that the temperature T of the weld zones varies as a function of time t in the manner shown in Fig. 4, it being estimated that the maximum temperature remains about 100°K below the melting point of nickel (1700°K approximately). With the aid of Fig. 3, the Peltier coefficient P

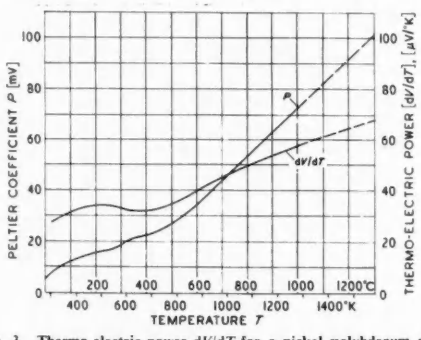


Fig. 3. **Thermo-electric power dV/dT for a nickel-molybdenum combination and Peltier coefficient P as functions of temperature T.**

is plotted in Fig. 4 as a function of time t, and also the Peltier power $Q_P = Pi$. The shaded area bounded by this latter curve gives the total Peltier heat, which amounts to $4{\cdot}2 \times 10^{-2}$ joule. The capacitor, which contains the welding energy, has a capacitance C of $6{\cdot}7 \times 10^{-6}$ farad and is charged to a voltage V_C of 980V. The energy released on discharge is $\frac{1}{2}CV_C^2 = 3{\cdot}2$ joule. Estimating that about half of this generates useful heat in the immediate vicinity of both junctions, then 0·8 joule is available per weld. The calculated Peltier heat comes to about 5% of this value. The quantities of heat available for the one weld and for the other thus differ by 10%. This makes it a plausible assumption that the Peltier effect causes a significant discrepancy between the two welds.

The Thomson Effect

Although this article is primarily concerned with the Peltier effect, it is considered that mention should also be made of the Thomson effect, i.e., when a current flows through a wire in which a temperature gradient exists, an amount of heat, in addition to the joule heat, will be developed or absorbed, depending on the direction of the current. The quantity of Thomson heat Q_{Th} developed, or absorbed, per second in an element dx of such a wire is

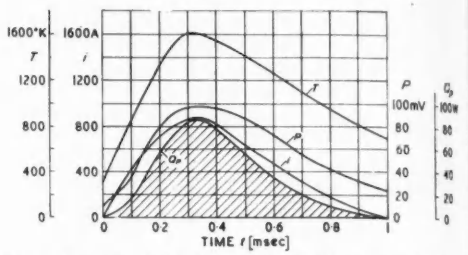


Fig. 4. **Assumed variation of temperature T with time t, and welding current i, Peltier coefficient P, and Peltier power Q_P as functions of time t.**

given by

$$dQ_{Th} = \sigma i \frac{dT}{dx} dx \qquad (3)$$

The proportionality factor σ, which is the Thomson coefficient, is dependent on the material of the wire and on the temperature.

In the case under consideration, appreciable temperature gradients will arise in the molybdenum wires between the weld zones and the welding electrodes. It is therefore reasonable to ask whether perhaps the Thomson effect, too, will have any significant influence on the weld. The Thomson coefficients of a number of metals (including molybdenum) have been measured as a function of temperature by Lander,* and are shown in Fig. 5. To be able to say anything about the influence of the Thomson effect, it is assumed that, at the moment when the weld has reached its maximum temperature (1600°K), the temperature of the electrode tip is 600°K. It is also assumed that the temperature gradient in a molybdenum wire is linear from weld to electrode. Near the junction, where the temperature is higher than 1000°K, the Thomson coefficient in the molybdenum wires is negative, as shown in Fig. 5, in which the sign convention adopted is that a positive value of σ means that heat is developed when the temperature gradient and the current are in opposite directions. A simple calculation shows that, in this part of a molybdenum wire, the Thomson power Q_{Th} at the moment under consideration is about 5 W. From Fig. 4, the Peltier power is then about 80 W.

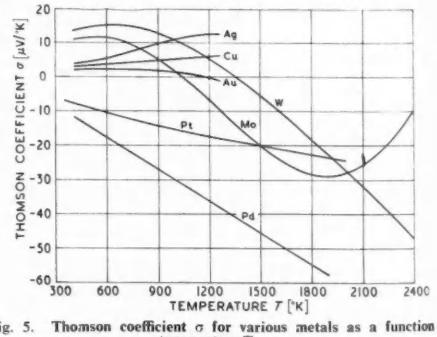


Fig. 5. **Thomson coefficient σ for various metals as a function of temperature T.**

Thomson heating is thus much smaller than Peltier heating and may be assumed to have no significant influence on the weld. It will have still less influence if thicker wires are welded, for in this case the Thomson heat will not be so concentrated at the junction.

* J. J. Lander : *Phys. Rev.*, Vol. 74, 1948, pp. 479–488.

Motion-Picture Technique for Studying Grinding Phenomena

By K. E. SCHWARTZ. (From *Industrie-Anzeiger*, Vol. 80, No. 92, November 18, 1958, pp. 1391–1395, 11 illustrations)

IF the changes in the structure of a particular selected area of a grinding wheel are photographed after each revolution or after a selected number of revolutions, deductions can be made about the phenomena occurring during grinding. However, such an observation requires extremely low exposure times, in conjunction with accurate and reliable synchronization. Thus, for a photographic definition within 0·1 mm and a magnification of ×10, the movement of the grinding wheel during exposure must not exceed 0·01 mm; if the wheel has a surface speed of 30 metres/sec, an exposure of $3{\cdot}3 \times 10^{-7}$ sec is required. The problem is therefore beyond the range of direct spark photography, but has been solved, as described in this article, by reducing grinding-wheel speed to about 10 metres/sec and by using a motion-picture camera and a special optical compensation technique.

As shown in Fig. 1, the 16-mm camera has a drive connected to the grinding-wheel spindle by means of a flexible shaft and change-gears, permitting a choice of exactly one frame per revolution of the wheel, or one frame for every 5, 25, 125, or 625 revolutions. The photographic light source, a "super-stroboscopic" type of flash lamp with an exposure time of 1×10^{-6} sec, is directed at an angle of 45 deg. to the surface to be investigated. For synchronization of this light source, the light from a small unilinear filament lamp is reflected first from a fixed mirror and then from a mirror rotating on the grinding-wheel spindle, so that, at a fixed position of the spindle, it is directed through a lens to a photocell which controls the flash lamp via a wide-band amplifier. The amplifier can be blocked electrically by contacts connected to the output shaft of the change-gears, so that only one flash per frame is obtained at each selected film speed.

Optical compensation, similar to that used for the compensation of film movement in high-speed cameras, is added to the system in order to increase the permissible grinding speed and also to extend the possible time of exposure. It basically consists of a rotating and an adjustable mirror (Fig. 2), arranged in such a way that, as a result of the rotation of the mirror, a point on the rotating grinding wheel can remain fixed in the image plane throughout the period of exposure. The other mirror can be adjusted to compensate for any change in the radius of the grinding wheel, and can also be tilted and turned for accurate centering of the image on the film. An adaptor is provided for fitting various objectives, giving linear magnifications from ×2½ to ×10.

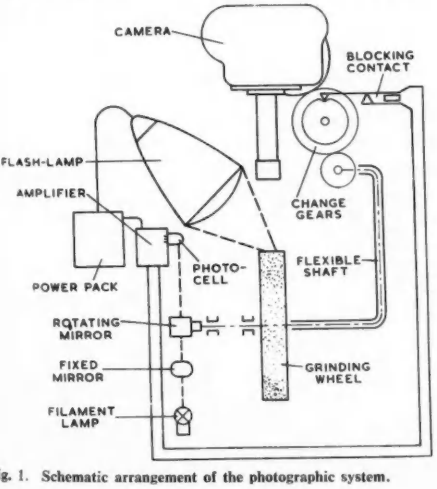


Fig. 1. Schematic arrangement of the photographic system.

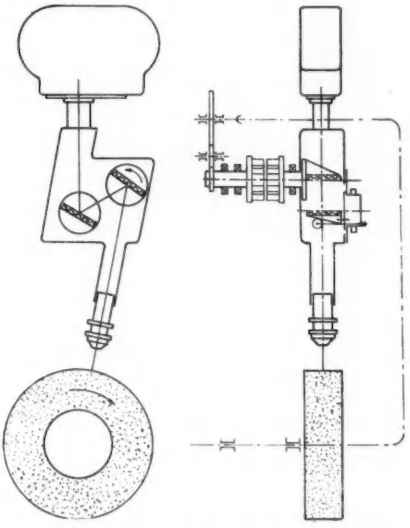


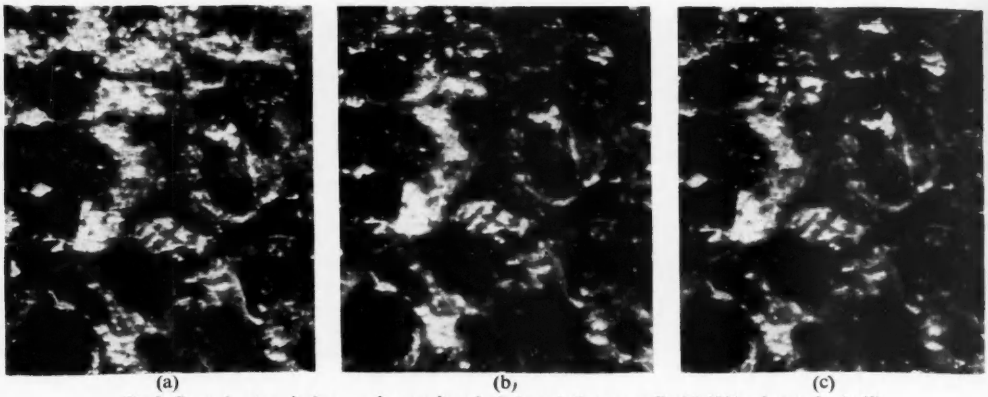
Fig. 2. Schematic arrangement of the optical compensation system.

Fig. 2 shows the arrangement of the mirrors and the mechanical drive. A tubular coupling connects the flexible shaft to gearing of suitable ratio, and the output shaft of the gear carries a coupling consisting of two permanent magnets, with a copper disc on one magnet, to act as an eddy-current brake for easier starting and as a damper. The coupling is therefore torsionally elastic, so that pitch errors in the gears are not transmitted. The complete camera, with optical compensation, the drive, and the synchronization control of the flash lamp are mounted on one rigid plate, which is securely fixed to the grinding machine, so that vibrations in the whole system are excluded. Inspection of the wheel is arranged opposite the point of grinding, and the use of oblique illumination increases contrast, owing to the shadows cast by the projecting grains. The rather complicated adjustment of the camera is checked by a special lens before insertion of the film, which may be black-and-white or colour. The grinding machine is equipped with an automatic feed, enabling the operator to devote his entire attention to the camera system.

Analysis of the Grinding Process

Using this equipment, investigations of phenomena occurring during grinding have been carried out, and an analysis of the grinding process has been made. The most important results of this analysis may be summarized as follows:—

(1) With a feed of from 10 to 40 μ, only a few of the visible points of cutting grains take part in the grinding action. These cutting points are revealed by their charac-



(a) (b) (c)

Fig. 3. Successive stages in the wear of a corundum wheel when grinding a normalized 0·45% carbon steel. (×40)

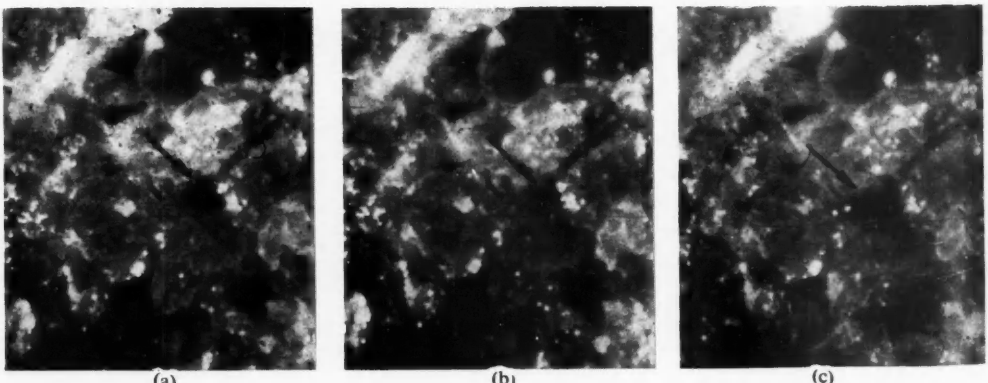
teristic wear surfaces, and occasionally also by steel chips adhering to the cutting grain from one revolution of the wheel to the next, when they break off or are replaced by other chips.

(2) In the grinding of steels, wear is mainly restricted to the points of grains, where wear surfaces which are comparable with those of turning tools are formed. Fig. 3a shows an area of a 60-grit corundum wheel after dressing, while Figs. 3b and 3c show the stages of wear of the same area after 16 min and 30 min respectively during the grinding of a normalized 0·45% carbon steel at a surface speed of 10 metres/sec. Removal of grains occurs only in isolated cases when the grains are no longer tightly bonded, either immediately after dressing the wheel or as a result of high stress applications. No self-sharpening by break-away of worn grains was observed.

(3) While it is true that the chips from brittle steels usually adhere to the wheel from one cut to the next, soft materials produce very plastic chips which adhere firmly to the wheel and are not removed by centrifugal force, by the jet of coolant, or by repeated cutting. On the contrary, they tend to fill up the pores of the wheel progressively, and finally weld together under the high temperatures produced by pressure and friction. This "smearing" action is illustrated in Fig. 4, which refers to a 46-grit corundum wheel at a surface speed of 10 metres/sec used for grinding a 1%Cr case-hardening steel. This smearing action impedes further cutting and leads to rubbing and burn marks on the ground surface. Suitably coarse dressing conditions may increase cutting life under these conditions by increasing the size of the pores in the wheel.

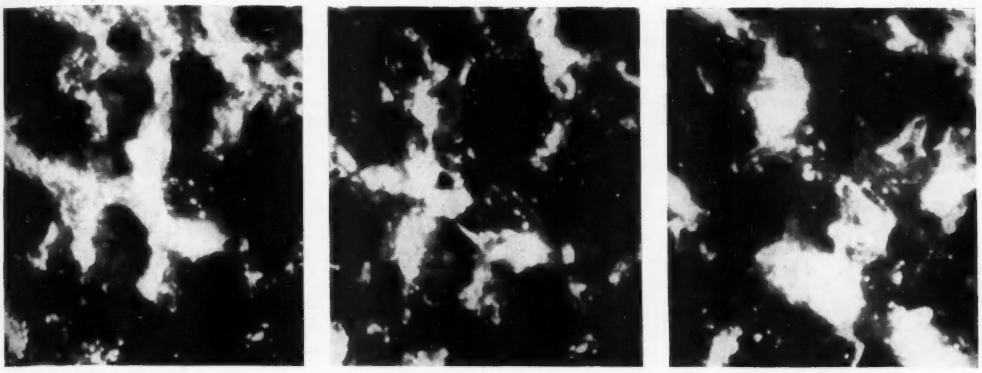
(4) If the wheel is stressed very highly during grinding, temperatures can be raised beyond the melting point of a steel; hollow spheres of from 10 to 100 μ diameter approximately can be produced by melting and rapid cooling, and some of them can adhere to the wheel. The high temperatures produced can easily alter the surface structure of the steel and can cause grinding cracks or decarburized layers. Under certain conditions, this can occur even with a newly dressed wheel; in other cases, it is observed only after some time and is caused by increasing bluntness of the grains, indicating the end of their useful cutting life and the need for redressing the wheel.

(5) When grinding high-speed steels or hard metals, the grains are blunted more quickly, and more grains tend to break away than is the case when grinding steel, so that there is a certain amount of self-sharpening. This is illustrated in Fig. 5, in which Fig. 5a shows part of a 46-grit silicon carbide wheel after dressing, while Figs. 5b and 5c show the appearance of the same part of the wheel during the grinding of a hard metal at a surface speed of about 8 metres/sec. Fig. 5b shows the surface after ten revolutions of the wheel, and Fig. 5c the resharpened structure after grinding for 2½ min. It should, however,



(a) (b) (c)

Fig. 4. Smearing action of a 1%Cr case-hardening steel during grinding with a corundum wheel, showing (a) a metal inclusion formed by welded chips, (b) the start of a new inclusion at the same spot, and (c) a fixed irremovable inclusion. (×40)



(a) (b) (c)

Fig. 5. **Self-sharpening of a silicon carbide wheel during the grinding of a hard metal.** (×40)

be understood that this self-sharpening action does not continue indefinitely, and the wheel must therefore be dressed at intervals, since the irregular break-away alters its shape. Moreover, break-away is not confined only to single grains but to groups of from three to five simultaneously, so that the porosity of the wheel tends to increase, with a corresponding decrease in the number of actual cutting grains and a sharp rise in the rate of wear. It should also be appreciated that, owing to the brittleness of hard metals, no adherent chips are formed, and the wheel structure remains very open.

(6) As hard metals can only be ground with a sharp wheel and as single grains wear rapidly, self-sharpening is indispensable. As a result, the wheel must have a very soft bonding agent, as was the case with the wheel referred to in Fig. 5, whereas the wheels in Figs. 3 and 4 had bonding agents which were not quite as soft. The effects of the bonding agent can be altered to a certain extent by varying grinding speed, lower speeds producing a softer effect. Thus, at a surface speed of 8 metres/sec, rapid break-away of grains was observed, single grains making only about 25 to 30 cuts from the first signs of wear to actual break-away. At twice this speed, break-away of the grains was less pronounced, though the attainable removal rate of work material was correspondingly lower. This motion-picture technique therefore appears to be very suitable for estimating optimum conditions of bonding strength and cutting speed.

U.S.A.

Properties and Applications of Molybdenum Coatings

By H. W. Schultze, R. R. Freeman, and J. Z. Briggs. (From *Materials in Design Engineering*, Vol. 49, No. 1, January 1959, pp. 76–81, 4 illustrations)

Because of their unique combination of properties, molybdenum coatings have been adopted for a number of industrial products during the last few years. These coatings can be produced by various methods, the most important factors in selecting the best coating method for a given application being the type of material to be plated, the maximum processing temperature, the rate of deposition, and the equipment needed. In most cases, consideration of these factors will limit the choice to one or two coating processes.

Major Types of Coating Procfsses

An ordinary sprayed or metallized molybdenum coating can be applied simply by using a wire-type metallizing gun and oxyacetylene gas. There are no limitations on the sizes of parts that can be coated, although molybdenum spraying is slower than other types of metal spraying. Spraying efficiency (metal deposited) is about 87%. Sprayed molybdenum is generally unmachinable and must be ground to final dimensions.

Ceramic metallizing (not to be confused with conventional metal spraying or metallizing) is a specialized process used to produce ceramic-metal seals in electronic equipment. The coating is applied by brushing or spraying a mixture of molybdenum and manganese powders (in a weight ratio of about 4 to 1) on the ceramic, which is then fired in oxygen-free hydrogen at about 2350°F for 15 to 60 min. The metallized ceramic is then plated with nickel or copper, refired in hydrogen at 1830°F for 10 min, and assembled with the metal parts by brazing.

The electrodeposition of molybdenum has proved comparatively difficult. Conventional deposition methods generally produce mixtures of molybdenum oxides, or extremely thin, non-protective films of molybdenum. On the other hand, electrophoretic deposition offers certain definite advantages over electrodeposition. The process is rapid and economical, has high throwing power, and permits a large amount of material to be deposited uniformly over irregular shapes.

Electrophoretic coatings are produced from a dispersion of finely divided molybdenum in a non-aqueous solvent. A sintering step in a reducing atmosphere at about 2200°F transforms the deposits into a homogeneous coating. The coating may be densified before or after sintering, to provide an impermeable coating. Hydrostatic pressing at 50,000 to 100,000 psi has been found most efficient. Where heavy coatings are needed, it may be desirable to build up successive layers with intermediate sintering and densification.

Electrophoretic molybdenum coatings machine well

and do not peel from the base metal. At present, the size of parts that can be coated is limited to about 1¾ in. in diameter by 14 in. in length; however, newer equipment is expected to accommodate diameters up to 5 in.

A comparatively rapid method of producing molybdenum coatings in a continuous operation is vapour deposition, which is accomplished by forcing a plating gas containing a volatilized molybdenum compound past the heated base metal in a partially evacuated system. The molybdenum can be deposited from either molybdenum hexacarbonyl or molybdenum pentachloride. The hexacarbonyl is decomposed by heat and can be used alone or with hydrogen as a carrier. The pentachloride is reduced by hydrogen, and helium or argon may be used as a carrier gas to eliminate premature reduction and give closer control.

A comparison of the carbonyl and pentachloride processes shows that, for the same pumping capacity, the rate of decomposition is considerably lower for the carbonyl than for the pentachloride process. However, carbonyl plating can be carried out at lower temperatures. It is easier to obtain a ductile, machinable deposit from the pentachloride than from the carbonyl process. On the other hand, the carbonyl process can be modified slightly to produce deposits of molybdenum carbide, molybdenum sulphide, or molybdenum boride.

Molybdenum pentachloride has been used (on a laboratory scale) for the continuous plating of iron, copper, and molybdenum wire, in lengths up to 1000 ft. This wire can be spooled and moderately deformed without damage. The process has also been used to produce a 0·004-in. molybdenum plate on the inside of steel tubes of 1 in. i.d. and 20 in. length.

Properties of Molybdenum Coatings

In general, the physical and nuclear properties of molybdenum coatings are similar to those of solid molybdenum. A notable similarity is their low coefficient of thermal expansion, which for molybdenum coatings is $2{\cdot}7 \times 10^{-6}$ per °F (32° to 200°F), and for solid molybdenum $3{\cdot}0 \times 10^{-6}$ per °F (room temperature).

Both the thermal and electrical conductivity of molybdenum vary somewhat with density and constituents. The density of sprayed molybdenum coatings is about 85 to 95% that of solid molybdenum. Density can even be further increased by sintering, particularly if small amounts of nickel, cobalt, or iron are added to produce a liquid phase during sintering. Electrophoretic coatings have a density of about 90%.

Sprayed molybdenum coatings have low shrinkage stresses; this is sometimes the deciding factor in selecting sprayed molybdenum over other sprayed metals. Also, the moderate thermal neutron cross-section of molybdenum coatings makes them more desirable for nuclear applications than some other metal coatings.

Molybdenum carbide coatings deposited by the carbonyl process have properties quite different from those of molybdenum metal. The special properties of these coatings can be used to advantage in electronic components such as electrodes and grids; they combine low electron emissivity with good resistance to softening at high temperatures.

Excellent adhesion is a characteristic of almost all molybdenum coatings. In most cases a limited amount of diffusion is required for good bonding. Because of insufficient diffusion, many of the coating methods will not give an adherent coating on copper. Conversely, flash coatings of nickel or cobalt are often used on iron and steel to minimize excessive diffusion, which can cause the formation of a brittle intermetallic phase. Also, the formation of molybdenum carbide on the base metal in the carbonyl process produces a non-adherent coating which is likely to spall off. Consequently, plating conditions must be adjusted to give a low carbon content in the layer next to the base metal.

Molybdenum-plated parts can generally be deformed considerably without peeling. The good bond strength of electrophoretic coatings is demonstrated by their resistance to thermal cycling and shock. Sprayed coatings have bond strengths of 3000 psi and higher.

The hardness of molybdenum coatings varies widely and depends largely on the degree of purity. High-purity deposits are relatively soft, while deposits containing large amounts of carbon are hard. The ductility of a molybdenum coating depends on its carbon and oxygen content, as well as on its hardness. Ductility usually varies with hardness, but this is not always true. The presence of molybdenum carbide in carbonyl deposits, for example, produces brittleness with no appreciable increase in hardness.

Elongation values as high as 10·8% have been reported with stripped coatings vapour-deposited from molybdenum pentachloride. These coatings were specially designed to have a very low carbon (0·003%) and oxygen content, and were reduced 85% by rolling prior to vacuum annealing at 3800°F for various periods.

The strength of a molybdenum coating is closely related to deposit structure. Vapour-deposited and other coatings with columnar structures have poor lateral strength. Molybdenum plated on steel by the carbonyl method has an average shear strength of 100,000 psi in the plane parallel to the bond; the shear strength normal to the bond is only 25,000 psi, because of the columnar crystals.

Sprayed molybdenum coatings have low strength parallel to the layers of the deposit. The strength of sprayed molybdenum is adversely affected by oxygen content. Normally, sprayed coatings have a tensile strength of about 7500 psi and 0·03% extension under load.

Tests on coatings deposited by the pentachloride method already mentioned have shown a stress of 42,000 to 69,000 psi and an elongation ot 6·6 to 11·3% at the fracture point. The higher strength of the pentachloride coatings is believed to be the result of their superior structure and lack of longitudinal flaws.

Molybdenum coatings have extremely good wear resistance under a variety of conditions. Sprayed parts, especially, show very high wear resistance when running against bronze and babbitt. In many cases the life of the softer mating surface is also increased.

Similar results have been obtained with vapour-deposited coatings, especially on titanium. Thus, a hard steel ball can produce appreciable wear and galling on both unlubricated and lubricated titanium. However, titanium plated with molybdenum by the carbonyl process can withstand thousands of strokes without lubrication. It is claimed that a good wear-resistant molybdenum coating can be applied to an annealed titanium alloy in 1 or 2 hr without changing the structure or properties of the metal.

The corrosion resistance of a molybdenum coating is markedly influenced by its structural soundness. A porous coating, such as sprayed molybdenum, does not give much protection in aqueous media. Even if the coating is not corroded, the base metal can be attacked through the pores. The corrosion resistance of dense coatings,

such as electrophoretic and vapour-deposited plates, appears to be similar to that of solid molybdenum. Thus, high resistance can be expected to such reducing acids as hydrochloric, hydrofluoric, sulphuric, and phosphoric acids, even at high concentrations and temperatures.

To resist corrosion by liquid metals, molybdenum coatings do not have to be perfectly dense and non-porous. Most molybdenum coatings have good resistance to liquid sodium, as well as to many other liquid metals such as bismuth. However, British tests have shown that sprayed molybdenum can disintegrate in liquid sodium when the liquid metal penetrates the coating and destroys the adhesion between the molybdenum and the base metal.

All molybdenum plates have the same susceptibility to oxidation as solid molybdenum. Consequently, plates cannot be used in air or oxidizing atmospheres at temperatures over 750°F, unless they are treated with some type of protective coating.

Applications of Molybdenum Coatings

The unusual combination of properties offered by molybdenum coatings has resulted in a number of interesting applications. Some of these have been quite successful commercially, whereas others are still in an advanced stage of development.

In certain types of electronic tubes, such as ultra-high-frequency and very-high-frequency tubes, it is often necessary to use ceramics rather than glass. Since the ceramic forms part of a vacuum envelope, a good ceramic-metal seal is needed, and a metallized molybdenum coating has proved extremely satisfactory in effecting such a seal.

One of the most interesting applications of molybdenum coatings is their use in experimental all-aluminium automotive engines. Ordinarily, a conventional aluminium piston does not function well when bearing against an aluminium cylinder-wall. However, this problem has been overcome by coating the walls with a sprayed molybdenum bond-coat and a sprayed steel top-coat. This composite coating has provided a longer life than that obtainable with conventional engines. Favourable results have also been obtained when using molybdenum coatings alone, particularly on cylinder-walls and brake-drums. Tests on a portable aluminium petrol engine have caused a breakdown in the chromium plate on cylinder-walls after less than 400 hr, whereas molybdenum-sprayed parts showed little or no wear after 4000 hr.

Mismachined automotive crankshafts are salvaged by spraying with 0·010 to 0·040 in. of molybdenum before grinding to size. The sprayed shafts are said to surpass all quality requirements and to have exceptionally fine bearing surfaces.

Sprayed molybdenum coatings have also proved extremely effective in lengthening the life of automotive production equipment. Thus, the use of a sprayed molybdenum coating on forming punches for producing flanges for the ends of axle housings has made it possible for these punches to produce up to 40,000 parts before respraying is necessary; previously, the uncoated punches had an estimated maximum life of 300 parts, because of loading and welding of metal on the punches.

In aircraft, sprayed molybdenum coatings are used on engine ball-joint couplings to prevent excessive wear. Of all the hard-surfacing methods considered, only sprayed molybdenum could be applied at a temperature low enough to prevent distortion and loss of strength of the base metal. Sprayed couplings have shown no sign of wear or fretting corrosion after 150 hr of engine testing. The coatings are now specified for overhaul salvaging, as well as for new parts.

Molybdenum coatings have been used commercially and experimentally in many nuclear applications. However, service results have often been unobtainable because of security restrictions.

Molybdenum coatings have been tried in experimental fuel elements, both for corrosion protection and as a carrier for fissionable material. In one design, beryllia moderating cores were to be coated with a fissionable material in a molybdenum matrix, the molybdenum serving as a diffusion barrier and fuel carrier. Heated and densified molybdenum coatings applied to beryllia have been found to maintain a good bond after 100 hr at 2000°F, followed by fifteen thermal cycles between room temperature and 2000°F. Shrunk-on molybdenum rings could not maintain adherence after similar testing.

Molybdenum coatings have also been tried in pin-type metallic fuel elements. Each element is composed of a base wire of molybdenum, a fuel layer of 20% uranium dioxide/80% molybdenum, a diffusion barrier of pure molybdenum, and an outer layer of chromium for corrosion protection. The diffusion barrier is applied by electrophoretic deposition and has satisfactory bonding and density.

In addition, electrophoretic coatings have been used on Inconel shafts in an experimental application requiring good bearing properties and resistance to corrosion by fused salts. Another application in the research stage uses molybdenum to coat graphite and stainless steel to make them impermeable to hydrogen and other gases.

Other applications of sprayed molybdenum coatings include their possible use as gun liners. They have also proved satisfactory in a number of applications requiring high wear resistance. In some of these applications, sprayed molybdenum was originally adopted for salvage operations but, because of the excellent performance of the coatings, is now frequently specified for new parts, e.g., grinding-wheel spindles and lathe-ways.

Another wear-resistance application is the use of sprayed molybdenum on large fan blades used in a British coal-dust extractor plant. To determine the effectiveness of the coating, a small area near the base of the blade, where wear was most severe, was sprayed with 0·003 to 0·005 in. of molybdenum. After 1500 hr of operation, the sprayed area showed hardly any sign of wear, whereas the rest of the blade was reduced to wafer thickness.

Possible Future Applications

One of the most important future uses suggested for molybdenum coatings is as interior platings to reduce erosion and corrosion in non-oxidizing, high-temperature, high-pressure chemical systems. A typical example would be a high-temperature polymerization system where extreme flow velocities could cause erosion. Specific parts lending themselves to such protective plating include valves and valve trim, tubing and piping, heat exchangers, and reactor vessels.

Some relatively unexplored fields offering encouraging possibilities are (1) the production of inexpensive carbide tools and dies by using controlled thermal decomposition of hexacarbonyl to deposit hard molybdenum carbide coatings, (2) the use of molybdenum or molybdenum carbide coatings on electroforming dies and wear plates, (3) the use of vapour-deposited molybdenum sulphide films as lubricating surfaces, (4) the siliconizing of molybdenum deposits to provide oxidation resistance, and (5) electroless molybdenum plating.

GERMANY

The Fatigue Strength of Flame-Cut Steel Specimens Repaired by Welding

By A. MATTING, H. WOLF, and H. D. STEFFENS. (From *Schweissen und Schnieden*, Vol. 11, No. 1, January 1959, pp. 8–16, 24 illustrations)

FLAME-CUTTING, introduced about fifty years ago, has been developed into a highly valuable and economic process. However, because the structure of the workpiece is altered in the heat-affected zone, flame-cutting can give rise to residual stresses which can cause distortions; in addition, the strength of the material may be reduced, particularly if it is required to withstand dynamic loads.

The affected zone can be machined down to eliminate these effects, but the time and expense involved in this operation, plus the wastage of material, make the process less economical. Nowadays, improved cutting techniques enable clean-cut edges to be obtained, with narrow tolerances and no appreciable reduction in fatigue strength. Nevertheless, there still is the problem of deciding how the inevitable defects occurring in flame-cutting should be dealt with. Such defects can be caused by intermittent pulses in the jet of oxygen, unevenness of cutter guidance, and segregations or foreign substances in the path of the cutting flame, such as oil, etc. Machining down to the root of the defect is not only costly, but also impossible when close tolerances are to be held. Thus, the repair of such defects by welding seems an obvious procedure, but up to now this method has not been common practice; in fact, it has frequently been considered unacceptable.

An assessment made a few years ago of the strength of forgings of highly stressed components which had been repaired by welding[1] indicated that the welding method might also be very useful in repairing defects in flame-cut edges It was therefore decided to investigate the dynamic fatigue strength of flame-cut specimens subsequently repaired by welding, and to compare the results with the behaviour of unwelded and milled specimens of similar shape The results obtained and the associated theoretical considerations form the subject of this article.

BEHAVIOUR OF MATERIALS UNDER DYNAMIC LOADS

When dynamic loads are applied to a material, its crystals are subjected to shearing deformations along their slip planes, with either alternating (two-directional) or pulsating (unidirectional) strains. Even below the fatigue limit, plastic deformations occur, owing to differences in stress distribution, and these deformations lead to stress concentrations and to hardening of the material.

According to Kochendörfer[2], fatigue strength can be regarded as a limit of permissible deformation. Masing[3] has put forward the hypothesis that the free paths required for deformation to take place are limited by local hardening, resulting from repeated strains in the plastic range. At high loads, the stresses can no longer spread out, and separation occurs. Späth[4] has suggested that local heating centres, or "micro-furnaces", are formed, with temperatures above the melting point and, when the fatigue strength is exceeded, the material can no longer recover by subsequent rewelding of its molten zones.

Taking into account these and other interpretations, it seems probable that fatigue fractures can be explained as follows:—The state of stress in the cross-section of a polycrystalline body is not uniform. Individual groups of crystals sustaining high stresses are deformed plastically, even at fairly low loads, owing to dislocations which take place and are propagated along the slip planes. The growth and collapse of these stress centres produce high local temperatures and intense ultrasonic waves which, by reflection, may result in standing waves, particularly in regions at distances of half a wavelength, thus accelerating the propagation of dislocations by an additional supply of energy. Owing to tensile stresses and increased temperature, an expansion of the lattice occurs, allowing gases from the material and its surroundings to diffuse along the paths of dislocations. Assuming that local melting occurs at highly stressed points, these diffused gases can prevent rewelding and can thus affect the cohesive strength of the lattice. Tests on cold-worked specimens under dynamic loads have shown that irreversible dislocations of atoms are associated with localized flow phenomena, which can be regarded as a preliminary to separations in the material[5].

The deformation capacity of crystallites is reduced by large numbers of dislocations blocking each other's paths, by diffused foreign atoms, and particularly by precipitated particles. The critical degree of alternating shear deformation, beyond which sliding at reduced stress occurs, is exceeded even with small deformation. Owing to excessive load, the cohesion of the structure can be destroyed at one point; a crack occurs, which, because of the stress concentration at its point of inception, can then develop until failure of the workpiece takes place.

RESIDUAL STRESSES IN WELDING AND FLAME-CUTTING

Residual stresses, with tensile and compressive regions of macroscopic dimensions, also occur in welding and flame-cutting, their hardening effect being very small. These stresses are due to incompatible conditions of stress, with partially elastic and partially plastic compensating actions. The material must permit a certain minimum degree of deformation, mild steel with a ferritic or ferritic-pearlitic structure being satisfactory in this respect, whereas a hard martensitic structure is not satisfactory. The main factor for a stress-reducing action is sufficient ductility[6]. After flame-cutting or welding, the state of stress is at least biaxial in the affected zones and cannot be calculated, since the stresses are not due to loads but to incompatible plastic deformation conditions. Welding stresses cannot be calculated in the same way as thermal stresses.

In flame-cutting and in welding, the residual stresses frequently reach the yield point. De Leiris and Bøllet[7] have shown that the position of the tensile-stress peak depends on the type of material. With non-hardenable steels, it reaches the yield-point value at the flame-cut surface. A hardenable steel develops residual compressive stresses at the edge, changing over to tensile stresses after a few millimetres, where they reach their peak value.

Under static loads, plastic deformations occur at an early stage in zones of maximum residual tensile stresses, and tend to relieve residual stresses to the extent allowed by the deformation of the material. If the deformation capacity is insufficient, cracks are formed. The material may now also produce a crack under pronounced multiaxial stresses. The shear-stress components required to deform a crystal appear to be considerably reduced in a triaxial state of stress. As a result, only an insufficient amount of plastic deformation is initiated, and a pure cleavage fracture is obtained[8].

Influence of Residual Stresses on Fatigue Strength

Under dynamic conditions, residual stresses are relieved to a certain extent, depending on the value of the first load application. If it is fairly high, the subsequent load cycles will contribute only very little to stress relief. If the material has a sufficiently high deformation capacity and the stress conditions still permit a sufficiently high level of shear stress, the stress-relieving action can be regarded as taking place in such a way that the stresses due to loading and the residual stresses reach the yield point at the maximum stress positions. Since it frequently occurs that positions of maximum tensile stress do not coincide with those most prone to fatigue fractures, the inference can be made that the influence of residual stresses is less for some materials, than, say, the influence of shape or structure. However, some materials are very sensitive to residual stresses in their behaviour under dynamic fatigue loads.

Survey of Fatigue Tests with Flame-Cut Specimens

Tensile and bending fatigue tests on flame-cut specimens were carried out by Graf[9] in 1936. Graf found that shaping or grinding the flame-cut surfaces increased the fatigue strength of steel specimens, and that smoothing these surfaces was as beneficial as, or even better than, machining away the affected zone. Koenigsberger and Garcia-Martin[10] observed that the fatigue fracture always originated at the upper edge of the cut, owing to considerable melting, while Koenigsberger and Green[11] showed that the geometrical pattern of the flame-cut surface has a marked influence, poorly cut surfaces possibly resulting in a decrease in fatigue strength of up to 30%. De Leiris and Ballet[7] attributed the decrease of about 23% in the fatigue strength of flame-cut specimens, compared with shaped and subsequently polished specimens, to the influence of residual stresses.

Tör, Ruzek, and Stout[12] noted a decrease in the impact strength of flame-cut carbon steels (0·15 to 0·20% C) compared with machined specimens, the decrease being eliminated by subsequent normalizing. As distinct from Graf[9], these authors held the view that the strength was decisively affected by structural changes, rather than by the surface condition. Erker[13] came to similar conclusions for applications in which high impact strengths are required. However, sand-blasting the surface is sufficient to obtain high values of fatigue strength. High-strength steels show an even greater reduction in fatigue strength (up to 50%) than mild steels in comparative tests of flame-cut and machined specimens.

Boeckhaus and Lenk[14] consider that the subsequent machining of flame-cut surfaces does not seem necessary for non-hardenable steels, which can be flame-cut without preheating, even where dynamic loading is involved, whereas it should be carried out with hardenable steels, owing to the danger of crack formation. It is only in special circumstances that non-heat-treated high-alloy steels can be flame-cut without exhibiting crack formation. No reports on tests of flame-cut specimens repaired by welding have been found in previous literature.

Shape and Production of Specimens

In the above investigations into fatigue strength, no shape of specimen was found which ensured that the fracture invariably occurred within the gauge length. Almost two-thirds of the flame-cut specimens fractured at the end of the parallel section or in the fillet transition, although the radius was greater than that normally used in tensile tests. Similar results were obtained with milled specimens without a heat-affected zone. It was therefore inferred that stress concentrations in the ridges of the flame-cut fillet region were responsible for the fractures.

In the present investigation, various sections were tried, optimum results being obtained with the section shown in Fig. 1. Besides being provided with very gradual fillets, the specimen has grooves, 2 mm deep, which are milled in the parallel section on both sides of the rolled material.

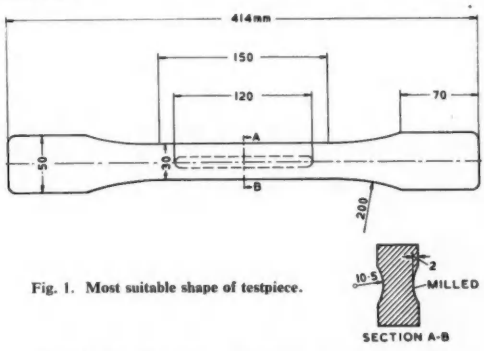


Fig. 1. Most suitable shape of testpiece.

The stress conditions in the specimens were first investigated by means of photoelastic models, with and without the grooves, the models being loaded in tension. Analysis of the fringe patterns showed that up to 60% increased stresses could be obtained if the gripping jaws were not parallel or if the specimen was obliquely clamped, but it was found that the grooves did not appreciably alter the stress distribution in the specimens.

In order to verify the photoelastic results obtained, a series of measurements was carried out on flame-cut specimens with wire-resistance strain gauges (1) to (6) located on the top and bottom edges and on the flat faces of the specimens, as shown in Fig. 2. The results showed considerable loading of the flame-cut lower edge between positions (1) and

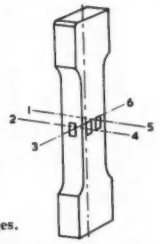


Fig. 2. Disposition of strain gauges.

(6), obviously caused by improper gripping (Fig. 3). Such asymmetrical loadings must be reckoned with, even with carefully made gripping elements. Thus, Fig. 4 shows the results obtained when the specimen was gripped at an angle of 0·8 deg. relative to its centre-line, and also indicates greater strains on the flame-cut surfaces than on the flat sides. Fig. 5 gives the values for a specimen in gripping elements having a certain amount of parallel misalignment. This type of loading evidently requires maximum deformability of the flame-cut surfaces.

Since the region of the edges of the flame-cut specimens is already in the plastic range, Hooke's law is not applicable. However, to facilitate visualization of the results obtained, nominal stresses, calculated in accordance with Hooke's law, are included in Figs. 3, 4, and 5.

All these tests show that plastic deformations occur at nominal stresses which are well below the yield point; even slight external loads, superimposed on the residual stresses, cause at certain points plastic deformations which are also affected to a considerable extent by the clamping conditions.

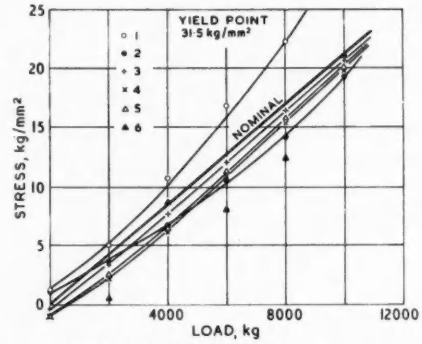


Fig. 3. Stress as a function of load at the centre of the testpiece, using conventional methods of gripping.

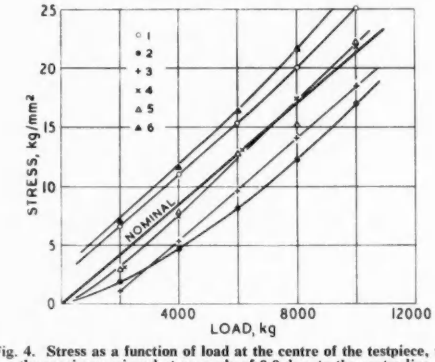


Fig. 4. Stress as a function of load at the centre of the testpiece, with the specimen gripped at an angle of 0·8 deg. to the centre-line.

Further tests were made by the brittle-lacquer method. With a specimen under pure tension, the cracks in the lacquer are perpendicular to the stress direction, i.e., to the centre-line of the specimen. On a flame-cut specimen tested under tensile load, the lines of strain were found to be at an angle of about 17 deg. relative to the transverse direction. Thus, in this case, there is a tensile stress with a torsional or shearing stress superimposed, the torsional stress being about one-third of the applied tensile stress. Such torsional stresses occur to a more marked extent on the rolling skin and on the flame-cut surfaces than on the edges themselves, and are easily obtained with imperfect gripping arrangements.

The materials used for making the specimens were heavy plates, 15 mm in thickness, of two different types of steel of the nominal percentage compositions shown in Table I.

TABLE I: COMPOSITION OF STEEL SPECIMENS USED [%]

Steel No.	C	Si	Mn	Cu	Al	P	S
(1)	0·15	0·24	0·53	—	—	0·018	0·025
(2)	0·17	0·39	1·13	0·17	0·026 –0·040	0·016	0·028

Steel (1) had a yield point of 29·4 kg/mm² and an ultimate tensile strength of 46·0 kg/mm², while steel (2) had a yield point of 35·6 kg/mm² and a UTS of 52·2 kg/mm². The elongation of steel (1), with a length/diameter ratio of 5, was 34·6%, as against 28·4% for steel (2), and necking was 54·4% for steel (1) and 42·7% for steel (2).

The specimens were cut with an oxy-acetylene torch

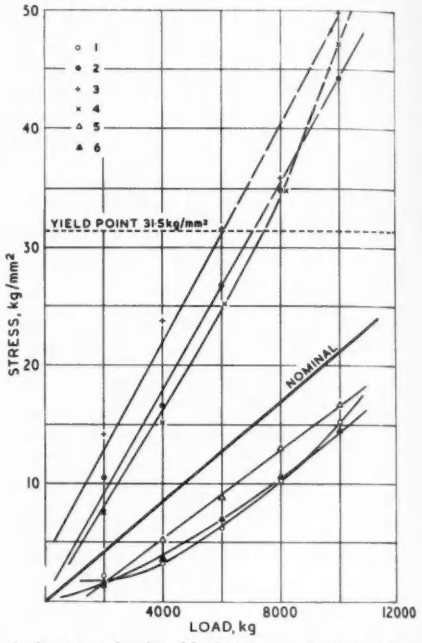


Fig. 5. Stress as a function of load at the centre of the testpiece, for specimens gripped with a certain amount of parallel misalignment.

on a flame-cutting machine, using a template, under conditions similar to those occurring in normal practice. A clean cut was obtained at cutting speeds of 320 to 340 mm/min for steel (1), and 270 mm/min for steel (2), the respective widths of cut being 1·8 to 2·1 mm and 2·1 to 2·3 mm.

Measurements of the surface roughness of the wavy flame-cut surfaces showed groove radii of 3 to 6 mm, on which were superimposed many discontinuities with radii of a fraction of a millimetre, representing stress concentrations which can reach high values.

Every localized heat treatment leads to distortion of the workpiece, and the specimens were found to have deviations of up to 0·7 mm width in their parallel section, despite all precautions.

The plate material itself had a slight curvature in the as-supplied condition, and this could not be rectified by flame-cutting. The middle sections of the specimens had deflections of 0·4 to 0·8 mm relative to the end sections. In pulsating tensile tests, the fracture of the specimens always occurred on the underside for specimens deflected upwards, whereas it occurred sometimes, but not always, on the upper side, with specimens deflected downwards, possibly because of differences in the residual stresses on the two surfaces of the plate. Owing to pre-heating and post-heating by the flame, the maximum residual tensile stresses are probably lower on the upper surface of the specimen. In any case, the hardness gradient and the stress gradient are smaller, whereas both gradients show very abrupt changes on the side away from the flame, so that stress concentrations of high magnitude can occur over small regions.

STRUCTURE OF SPECIMENS

As a result of flame-cutting, the cut surface shows an alteration in structure of limited depth (Fig. 6). The un-

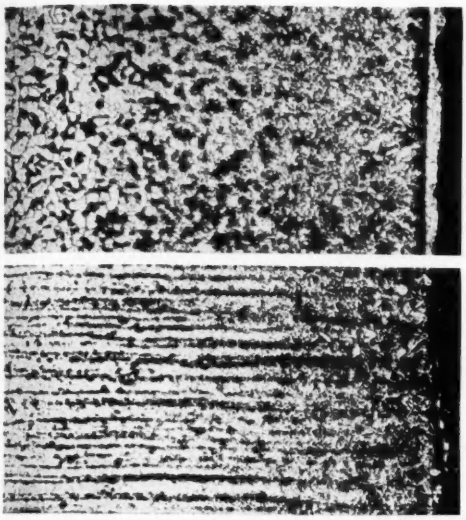


Fig. 6. **Alteration in structure of the heat-affected zone in the case of (*top*) steel (1), and (*bottom*) steel (2). (×60)**

affected material in both types of specimens consists of ferrite and lamellar pearlite, the lamellar structure being particularly noticeable in the case of steel (2). At a depth of 0·3 mm, ferrite-pearlite occurs in a Widmannstätten structure, with a fairly coarse grain. At about 0·9 mm from the edge, the lamellar pearlite changes into granular pearlite. At a distance of a few hundredths of a millimetre from the edge, a sorbitic structure can be observed, which changes further towards the edge into needles of martensite with residual austenite. The melted zone at the edge, 0·002 to 0·03 mm wide, develops in various ways; thus, on the roughness peaks, it presumably consists of a ferritic base, in which isolated austenitic areas with martensite needles are embedded. In the valleys, a narrow layer, composed solely of ferrite, is present.

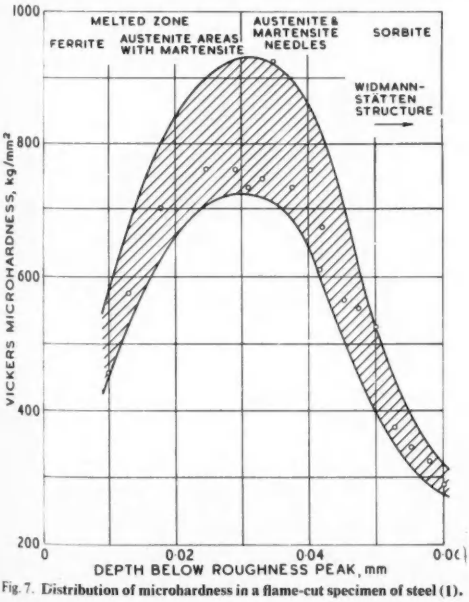


Fig. 7. **Distribution of microhardness in a flame-cut specimen of steel (1).**

Microhardness tests gave a Vickers hardness (under a load of 50 kg) of 331 kg/mm² for the sorbitic layer immediately adjacent to the Widmannstätten structure, and 543 kg/mm² at the transition of the sorbitic layer to the martensite (Fig. 7). The austenitic zone with coarse needles of martensite gave hardness values of 613 to 927 kg/mm². The melted zone with isolated areas of austenite-martensite gave hardnesses ranging from 460 kg/mm² (right at the edge) up to 766 kg/mm². The melted zone, probably consisting of a ferritic base with the isolated austenite-martensite areas, can have only a very low fatigue strength, because of its structure. This fact deserves further attention, in view of the very large numbers of fatigue cracks occurring in this zone.

In previous literature, the structure of the edge exposed to the flame and of the upper edge have been held responsible for the generation of incipient fatigue cracks. Photomicrographs show, however, that there is no difference in structural development and that no preferential conditions for fatigue fracture therefore exist as a result of structural differences.

Repair of Flame-Cutting Defects by Welding

For repairing flame-cutting defects by welding, the weld material should be the same as the base material, if perfect welds are to be obtained, but allowance must be made for the fact that pores and slag inclusions can be expected. Disregarding residual stresses, if the filler and the base metal are identical, there will be no stress raisers anywhere in the cross-section of the material when it is subjected to load, if pores in the weld are absent. However, if pores are present, they will act as internal notches, producing stress peaks whose value will depend on the modulus of elasticity E of the filler material, so that these peaks will be lower if a filler material with a low modulus of elasticity is used.

Welding repairs, using material with a low modulus of elasticity, have already proved successful in the case of highly stressed forgings[1]. As a result, it was decided to carry out tests with basic electrodes containing about 0·15% C, austenitic electrodes containing 18% Cr, 8% Ni, and 6% Mn ($E = 1{\cdot}67 \times 10^4$ kg/mm²), and electrodes containing 12% Al, 3·5% Fe, and 84·5% Cu ($E = 1{\cdot}13 \times 10^4$ kg/mm²), all of 2·5 mm diameter.

Analysis of Results

The fatigue behaviour of the specimens was investigated by determining time to rupture under pulsating tensile loads. The number of load cycles to rupture was found to be dependent, for all specimens, on load level, type of load, and clamping conditions. Non-uniform clamping led to stress concentrations at the ends of the parallel section of the specimens, the effects of these concentrations being more marked with flame-cut specimens (with residual stresses and notch effects due to surface roughnesses) than with milled specimens.

In general, milled specimens gave somewhat better values. There was more scatter with steel (1) than with steel (2), not so much because of differences in quality of the flame-cut surface but because of uneven clamping. The decrease in fatigue strength of the flame-cut specimens, compared with the milled specimens, became greater with increased values of maximum stress. A likely explanation is that the altered structure at the edges is less capable of withstanding the alternating shear deforma-

tions in the same manner and to the same extent as a structure not affected by heat. However, the tests showed that the influence of flame-cutting is small in comparison with the effect of clamping. Under perfect clamping conditions, the difference in fatigue life for specimens of steel (2) is about 15%, with an upper load limit 4·2% below the yield point; with an upper limit of 11% below the yield point, the difference in practice is hardly noticeable.

In tests on specimens of steel (1) containing defects, it was noted that the fatigue life of flame-cut specimens was low, even with low loads. In the case of non-defective flame-cut or milled specimens, the latter were only slightly superior at upper stress levels of 32·3 to 32·6 kg/mm², whereas defective flame-cut specimens, subsequently repaired by welding, showed considerable scatter in the results and on the average sustained considerably less load cycles at these upper stress levels. One reason for this result (apart from faulty welding and defective clamping) is that the upper stress level used in these tests was about 1 kg/mm² above the yield point of the material, so that the advantage of using a filler material with a lower modulus of elasticity was not utilized.

At a somewhat reduced upper stress level of 30·5 kg/mm², milled specimens of steel (1) again gave better values than flame-cut specimens. However, an interesting result was that there were no pronounced differences in the case of both flame-cut and milled specimens provided in both instances with a similar defect subsequently repaired by welding, the same values of fatigue strength being obtained, provided that burnt-in notches were avoided during welding. To prevent such burning, the arc should not be struck on the edge of the specimen, but on a metal plate in front of the specimen. Using this procedure, it was frequently found that the specimens no longer fractured in the weld-metal area. Austenitic and basic electrodes were found to be equally suitable for this purpose. Welding with the Cu-Al-Fe electrodes required somewhat more practice, and the lower fatigue life obtained at high load values are probably also associated with the lower fatigue strength of the filler material itself.

The results with specimens of both steels were basically similar, any differences becoming smaller when the upper stress level was moved down from the neighbourhood of the yield point. Clamping conditions and occasional defects, e.g., in the rolling skin, are then more important than the actual welding procedure.

The beneficial effect of austenitic weld metal in the presence of notches was not always confirmed. Thus, for example, the austenite formed often had very coarse grains (Fig. 8), despite welding in two passes. Coarse grain is also found in the adjacent Widmannstätten structure of the base material, the transition between the two types of structure beng very sudden, as indicated in Fig. 9, where a Cu-Al-Fe electrode was used. With basic electrodes, the transition from the weld metal to the base material develops continuously.

Numerous cracks, filled with weld metal, were found in the base material of a number of specimens, these cracks having evidently been formed during machining. These cracks can also be observed in Fig. 9. The fact that cracks can be initiated in this way is worth noting, as some specifications permit machining of flame-cut surfaces, but prohibit repairs by welding.

In the course of this investigation, it was found necessary to eliminate craters at the edges of the welds by careful grinding, since such craters frequently were a cause of fatigue failure. In a typical instance in which the crack first originated at a crater, the adjacent overloaded regions reduced stresses by flowing to such an extent that the opposite side of the crater became overloaded, and a crack developed which subsequently caused failure. For good-quality repairs by welding, the craters at the edges must be carefully removed, and sharp edges provided with a radius of about 1 mm. Such specimens have been found to give excellent fatigue strength. It is recommended that the grinding of craters be carried out in the direction of the stresses, and that, in addition, all edges of the plates be rounded off.

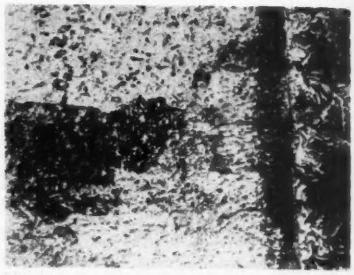


Fig. 8. Microstructure of weld metal and transition zone, showing coarse grains in the austenite and base metal. (×100)

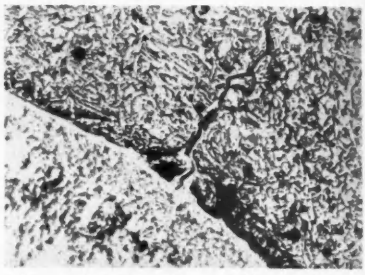


Fig. 9. Microstructure of a weld made with a Cu-Al-Fe electrode, showing sudden transition zone and cracks in the base metal, caused by machining. (×250)

REFERENCES

(1) E. Rubo: "Vorschläge zur Ausbesserung von Oberflächenfehlern an hochbeanspruchten Schmiedeteilen". Thesis, T. H. Hanover, 1956.

(2) A. Kochendörfer: "Plastiche Eigenschaften von Kristallen und metallischen Werkstoffen". Reine und angew. Metallkunde, Vol. 7, Berlin, 1941.

(3) G. Masing: "Lehrbuch der allgemeinen Metallkunde". Springer, Berlin, 1950.

(4) W. Späth: "Fliessen und Kriechen der Metalle". Metall-Verlag GmbH, Berlin, 1955.

(5) M. Hempel and E. Houdremont: *Stahl und Eisen*, Vol. 73, 1953, pp. 1503–1511.

(6) R. Weck: Vortragsreihe "Schweisspannungen" am Institut für Werkstoffkunde. T. H., Hanover, January 1958.

(7) H. de Leiris and M. Ballet: *Soud. Tech. Conn.*, Vol. 6, No. 11/12, pp. 271–279.

(8) A. Erker: *Schweissen und Schneiden*, Vol. 8, 1956, pp. 436–442.

(9) O. Graf: *Autogene Metallbearbeitung*, Vol. 29, 1936, pp. 49–57; and Vol. 30, 1937, pp. 321–323.

(10) F. Koenigsberger and Z. Garcia-Martin: *British Welding Jour.*, 1955, pp. 37–41.

(11) F. Koenigsberger and H. W. Green: *British Welding Jour.*, 1955, pp. 313–321.

(12) S. S. Tör, J. M. Ruzek, and R. D. Stout: *The Welding Jour.*, Vol. 30, 1951, pp. 446s–450s.

(13) A. Erker: *Schweissen und Schneiden*, Vol. 5, 1953, pp. 183–189.

14) K. Boeckhaus and W. Lenk: *Mitt. der BEFA*, No. 1, 1956.

FBC SPECIALS

... the key to a fuller life

Performance in many branches of engineering is getting very intensified, and what once passed as normal bearing practice is now as inadequate as a wooden wheel on a 100 m.p.h. car.

Some machines start out by packing enormous power into a small and often hot space, and there—as in some of the finest jet engines in the world—you will find FBC 'Specials' often running at fantastic speeds.

Other machines in the course of time get 'hotted up' to give far greater power or output—yet it is seldom that the original design has the space to take bigger bearings.

Here again FBC 'Specials' are saving the situation—for it is amazing what exacting duties can be carried out by the right kind of bearing, when one is really 'up against it' and enlists the aid of the right people.

Our engineers—to whom, of course, we have just referred—will always assist in the design and manufacture of 'Specials' to suit customers' problems.

FISCHER BEARINGS CO. LTD., WOLVERHAMPTON

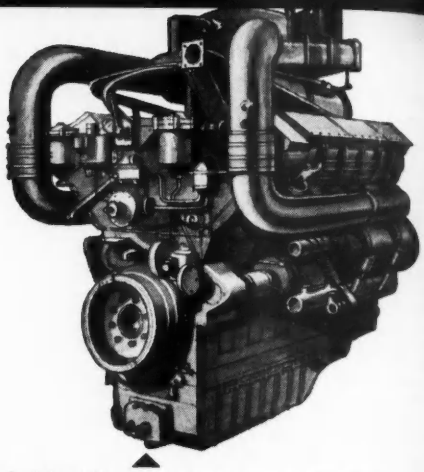
Fischer Bearings Company Ltd., and Timken-Fischer Stockists Ltd., Birmingham, are both subsidiaries of British Timken Ltd.

FBC

ALL BRITISH
BALL AND
PARALLEL ROLLER BEARINGS

Regd. Trade Marks
F.B.C. :: FISCHER

MAYBACH POWER MADE IN BRITAIN

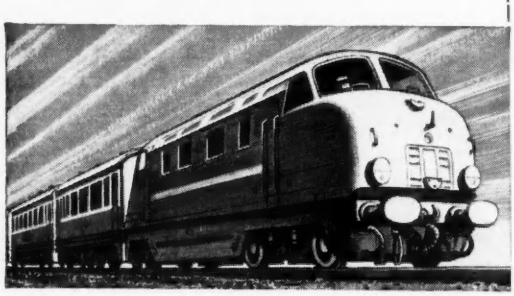


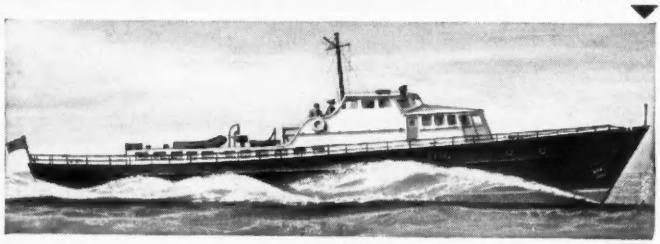
Typical of the MD range of engines is this Type 650 12-cylinder supercharged model with cylinders arranged in 'V' formation.

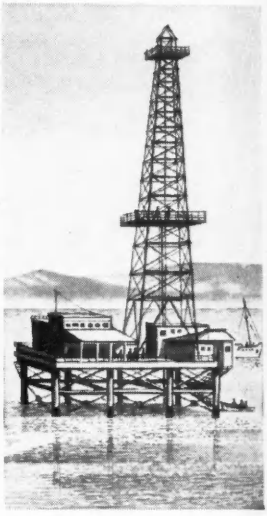
◀ Railway Traction 220-2,000 B.H.P.

Industrial Plant 220-1,750 B.H.P. ▶

Marine 220-3,000 B.H.P.







Armstrong Siddeley have the exclusive manufacturing and selling licence in the United Kingdom for the world-famous Maybach MD range of In-line and 'V' form diesel engines. These diesels range from 4-cylinder engines of 220 hp to 16-cylinder engines of 3,000 hp They have an outstanding record of performance and reliability over millions of miles on railways throughout the world, and are widely used for marine propulsion and industrial power generation of all kinds.

ARMSTRONG SIDDELEY

Maybach

DIESEL ENGINES

ARMSTRONG SIDDELEY MOTORS

Coventry, England

ENGINE BUILDERS TO THE WORLD

MEMBER OF THE HAWKER SIDDELEY GROUP

British Industrial Developments

Medium-Speed Diesel Engines

The latest additions to the Ruston range of medium-speed diesel engines produced by Ruston & Hornsby Ltd., of Lincoln, are the ATX and ATC engines, which incorporate a number of radically new features and which are not only power units of outstanding performance and extremely low fuel consumption, but embody all the necessary features contributing towards ease of maintenance and long service life under arduous conditions.

Both types are pressure-charged by an exhaust turbo-blower, the ATX series covering five models, of from 5 to 9 cylinders, with a power range from 705 to 1280 bhp at speeds of 500 to 520 rpm, while the ATC series, which incorporates an aftercooler, is also available in five models, of from 5 to 9 cylinders, with a power range from 900 to 1645 bhp at speeds of 500 to 520 rpm. The fuel consumption of the ATX series is 0·355 lb/bhp-hr, and that of the ATC series 0·339 lb/bhp-hr. Bore and stroke of both types are respectively 12½ in. and 14½ in. A typical industrial version of an AT engine is shown in Fig. 1.

The fuel pumps and injectors are of Ruston design, a separate fuel pump of the plunger, helix-release type being provided for each cylinder. Multi-hole injectors, of simple design to facilitate ease of service, incorporate an edge-type filter. A fuel filter, with easily cleaned elements, is fitted on the suction side of the fuel pump.

Major design advances incorporated in the AT series include the adoption of a very rigid crankcase design, providing exceptional dimensional stability for the main bearings, both from the point of view of alignment and the maintenance of bearing circularity under load. Also,

Fig. 1.

a cylinder-block casting of great torsional and bending stiffness has been used, in which flat surfaces have been avoided, so as to enable the cooling system to be operated under pressure, if required in certain applications. The cylinder head, secured by four long studs, is of very simple and rigid design. With the arrangement used, exceptionally good gasket sealing has been obtained. In addition, the large unrestricted spaces between the four cylinder-head studs have given complete freedom for adopting the oprimum shape of air and exhaust ports.

By a patented arrangement for transferring cooling water from the cylinder block to the cylinder head, the entire upper portion of the liner is effectively cooled. In the region of the combustion chamber, the scrubbing velocity of the cooling water over the liner has been increased so as to give higher rates of heat transfer where these are most necessary.

Other features include the use of a high-level camshaft, which acts directly on rollers at the ends of the valve rockers and on the fuel-pump tappets, providing a valve system of minimum inertia and of the utmost simplicity. In addition, forged I-section connecting rods

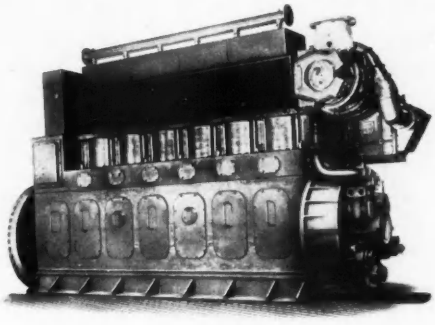


Fig. 2.

with integral large end-bearing bores have been adopted, the cap being secured by four bolts and the joint face inclined and located by multiple serrations. As a result, it has been possible to use a large end bearing of very generous proportions, capable of withstanding the highest loads encountered in service, whilst still allowing the removal of the piston-connecting-rod assembly through the cylinder bore.

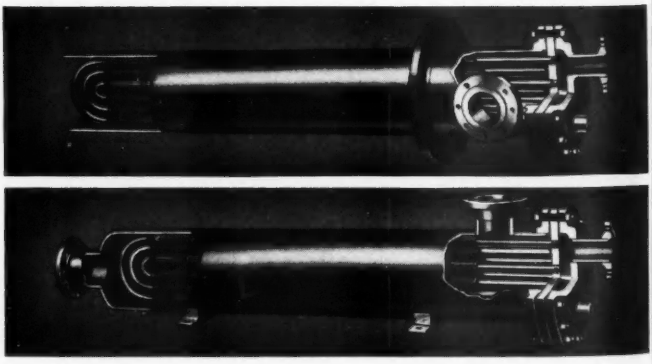
"Constant grain-flow" crankshafts, manufactured by the English Steel Corporation, with balance weights providing 97·5% compensation for the rotating forces in the engine, are used as standard throughout the range. These crankshafts are of exceptional rigidity, and in a wide range of applications their natural frequency is sufficiently high to render the use of a torsional vibration damper unnecessary. Pre-fit bearings supported on thin steel shells are used for both main bearings and large ends, and over-size bearings are available for use with re-ground crankshafts. Hence, the necessity for hand scraping is completely eliminated, and consistency of bearing performance in service is assured.

It should also be noted that these engines, by virtue of a number of special design features, are extremely versatile with regard to installation. Thus, for example, the seating of the cylinder block on the crankcase is symmetical, making it possible to build "handed" engines for marine propulsion or other applications from standard basic components. Also, the full power of the engine can be taken from either end of the crankshaft, which has identical flanges at each end. This feature, coupled with the great inherent torsional stiffness of the crankshaft, considerably increases the number of applications which can satisfactorily be met by the standard engine without the need for introducing extra equipment. Furthermore, "reverse-rotation" engines are available, using entirely standard parts, except for the camshaft, while auxiliary drives can be taken from five separate positions on the engine, i.e., from the right-hand or left-hand side at the flywheel end (chain drive), from the right-hand or left-hand side at the free end (chain drive), or from the front of the engine by a resiliently mounted gear drive, which can be arranged to drive six separate items of auxiliary equipment, as shown in Fig. 2.

man with a problem on his hands

The handling of high viscosity fluids—such as fuel oil—is a question of heating. Brown tank suction and line heaters, incorporating integrally-welded Fintubes, provide the answer. Careful design has produced heaters of compact dimensions, capable of extremely efficient heat transfer duties at relatively low "skin" temperatures. Brown welded fintubes provide—per linear foot—over eight times the effective heating surface of plain pipe. For full information on your specific application, send us details.

if he's wise, he'll get in touch with Brown Fintube. They're used to dealing with sticky problems.



BROWN FINTUBE GREAT BRITAIN LTD

CHESTER STREET, ASTON, BIRMINGHAM, 6. Tel: EASt 1171

London Office: 46 Westminster Palace Gardens, Artillery Row, LONDON, S.W.1. Tel: ABBey 2073 5.

Australia—Mr. K. C. Bottomley, Uniquip Pty. Ltd., 110 Willoughby Rd., Crows Nest, N.S.W.
Netherlands—Geveke & Co's Technisch Bureau N.V., De Ruyterkade, 113, Amsterdam C.
Belgium—Chaurobel S.A., Huizingen.

High-Speed Hacksawing Machine

Replacing their previous 8″ model, the Wicksteed "Hydramatic" 8″ × 8″ capacity high-speed hacksawing machine, announced by Charles Wicksteed & Co. Ltd., of Kettering, incorporates several new features and has an exceptional cutting performance. Thus, the use of a highly developed and improved hydraulic control unit enables fast and accurate cutting speeds to be obtained with thin 16 × 1½ × 0·062 in. blades, providing more rapid cutting at less cost per blade. Cuts may be taken at angles up to 45 deg. on bars up to 5 × 8 in., and two cutting speeds (70 and 130 strokes per minute) are provided, the drive being taken from a 2-hp motor through Vee-belts and gears.

Occupying a floor space of 54 × 24 in., the machine has two controls at the front for all functions. Once the required cutting pressure has been set, only the motor-starter button and a foot pedal need be used for each cutting cycle. An automatic lift to the bow and a motor cut-out are incorporated. The suds tank is hinged, and coolant supply is provided by a gear pump.

Oils for the Wet-Drawing of Wires

As announced by Chas. H. Windschuegl, Ltd., of London, E.C.3, sole distributors in the U.K. for the wide range of products manufactured by Chemische Fabrik Stockhausen & Cie., of Krefeld, Germany, two types of oils, designated "Unopol HMN" and "Unopol CB", are now available for the wet-drawing of wires.

Unopol HMN, a new type of wet-drawing oil, is a fatty-acid condensation product, which is non-ionic and is virtually free from water, salts, and ash. Of a yellow-brown colour, this oil produces turbid solutions of outstanding stability when mixed with from 20 to 200 times its volume of lukewarm water. These solutions are stable against dilute acids and against salts causing hardness of water, as well as against salts of polyvalent metals. No chemical reaction giving compounds which are not readily soluble can take place, so that the formation of sticky metallic soaps is prevented. Unopol HMN is basically intended for use in the drawing of fine or very fine wires, e.g., copper, bronze, brass, aluminium, iron, and steel. Particularly good results have been obtained in the drawing of copper wires with starting diameters of less than 0·5 mm. This oil has an outstanding lubricating effect, even in very dilute solutions, and the wires after drawing are characterized by an extremely clean, smooth, and bright glossy surface. Furthermore, because of the neutral reaction, there is no tarnishing or rusting of the wire from the residual film of oil, while the excellent compatibility of the product with the usual lacquers ensures trouble-free finishing of wires.

Unopol CB is a sulphated neutral oil intended for use as a glide and lubricating agent in the wet-drawing of stock made from copper, brass, bronze, iron, steel, etc. It gives particularly good service in the drawing of wires made from copper and copper alloys, and in this respect may equally well be used for coarse, medium, and fine drawing. It can also be used successfully in the drawing of hard steel wire. In general, metals drawn with Unopol CB can be perfectly tinned, galvanized, coppered, and lacquered; only in exceptional cases is previous defatting required. For use, the oil is first diluted with an equal amount of soft water at between 60 and 80°C, producing finely dispersed opal emulsions which can then be further diluted with the required amount of cold or tepid water, in accordance with the desired application.

Microtester for Surface Finish

The "Diavite" microtester for surface finish, manufactured in Switzerland by H. Hediger, of Winterthal, and now available in the U.K. from the distributors, Payne Products International Ltd., of Hounslow, Middlesex, is a robust and simple instrument which gives rapid and accurate measurements of surface finish and, as such, is not only suitable for use in the workshop, but also in the laboratory.

The instrument uses a tracer which carries a pick-up of 8-mm diameter, fitted with a slip-on type of skid, and encloses a diamond stylus, which is hydraulically moved across the surface to be tested with a constant oscillating motion and under a very slight pressure. The vertical movements of the stylus relative to the skid are converted into electrical impulses by means of an electro-mechanical transducing element and pass through an amplifier to an electrical indicator, which is calibrated to show the centre-line average of profile deviations, the pointer being unable to follow the rapid succession of peaks and valleys in the surface of the workpiece. In addition, the instrument is supplied with a second indicator for measuring the maximum depth of profile, provision being made for preselecting on the scale the maximum profile depth prescribed for the workpiece. Provided that this value is not reached during the finishing operation, a red signal lamp lights up intermittently, these signals being controlled by an electronic relay which responds to extremely short impulses, without any appreciable influence on the movement of the pointer. It is therefore possible to measure the maximum profile depth of scratch marks by turning a knob on the compensation scale until the red lamp is completely extinguished. The ranges provided

Putting two and two together and making five ! At least, that's how it appears when you consider the saving in time and cost by changing over to tapping screws.
Without doubt, the tapping screw does display a number of very definite advantages over the conventional machine screw. It obviates the use of nuts. With its self-locating point, it forms its own thread and eliminates a separate and expensive tapping operation. It makes for easier assembly, is stronger, cheaper and faster. And when used in conjunction with the Phillips recessed head, designed for power driving without damage to either work or worker, it is obviously safer. Putting two and two together, the tapping screw simply ensures a better job.
Why not change over to tapping screws and prove it for yourself?

Linread *tapping screws for economy and safety*

LINREAD LTD. COX ST. BIRMINGHAM 3

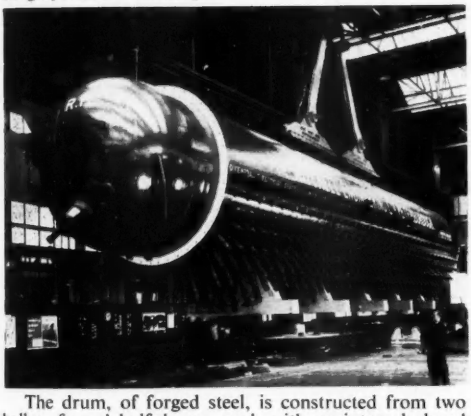
SLOTTED AND PHILLIPS RECESSED HEAD MACHINE SCREWS AND TAPPING SCREWS • HIGH TENSILE HEXAGON HEAD BOLTS AND SETSCREWS
AIRCRAFT BOLTS, SCREWS AND RIVETS • SEMS • RIVNUTS • CUSTOM DESIGNED COLD FORGED FASTENERS • ALEX SCREWPLUGS.

for measurement of maximum profile depth are 0 to 50, 0 to 150, 0 to 500, and 0 to 1500 micro-inches.

The instrument is normally supplied complete with one tracer, which fulfils most major requirements. This tracer has a measuring range of 0 to 300 micro-inches and can be used for measuring flat and curved (concave or convex) surfaces with a minimum radius of about 4 mm. Other tracers are, however, also available, including a type with a measuring range of 0 to 10 micro-inches for exceptionally fine flat and curved surfaces, and another type for measuring surface roughnesses of more than 300 micro-inches in the case of fairly rough flat surfaces only, or curved surfaces along straight generating lines.

Steam Drum for Skelton Grange Power Station

The unusual steam drum illustrated is the first of four similar drums produced by Thos. Firth & John Brown Limited, of Sheffield, to the order of Mitchell Engineering Ltd., for the Central Electricity Authority generating station at Skelton Grange, near Leeds. The drum, known as the " porcupine ", is 47 ft in length, has a bore of 66 in., and weighs 85 tons. Instead of the usual expanded boiler tubes, it is fitted with 879 welded stub tubes and attachments, and is intended to accommodate a design pressure of 1850 psi.

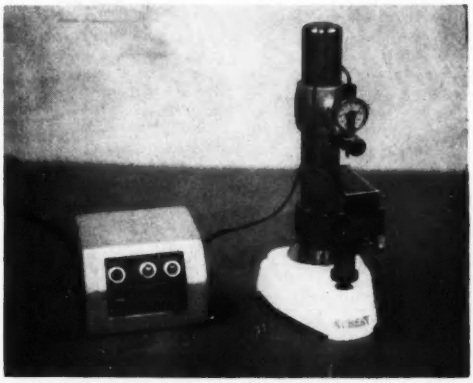


The drum, of forged steel, is constructed from two hollow forged half-drums, each with an integral closed end, the two halves being then joined together with a centre circumferential weld seam of 5¼ in. thickness. When assembled with a smaller receiver drum, and burning 55 tons of coal per hour, it will evaporate more than 860,000 lb of water into steam, which, passed through a single turbine, will generate 120 MW of electricity.

Precision Electro-Mechanical Comparators

Designed for automatic and semi-automatic inspection, the range of Rubert-Hommel electro-mechanical comparators announced by Rubert & Co. Ltd., of Cheadle, Cheshire, not only permit " go " or " no-go " gauging of up to twenty dimensions simultaneously, but also provide the operator with a means of reading the amount of error outside the tolerance on each dimension, if the indicator shows " no-go ".

As shown in the illustration, the equipment basically comprises a Hommel " Microcontac " electric dial gauge, which is mounted on a high-precision comparator stand and is connected by a cable to the indicator box at the left. In place of the comparator stand shown, a suction-clamped indicator stand or a miniature stand can be supplied. Also, for multiple gauging, special fixtures for measuring up to twenty dimensions simultaneously, and



angle connectors at 30, 45, 60, and 90 deg. are available.

The " Microcontac " is a jewelled type of high-precision dial gauge which can be supplied with scale divisions of 0·0001 or 0·0005 in. Tolerance for the electrical indication is adjusted by two lateral screws and, according to this setting, a green light is illuminated in the indicator box for " go ", a red light for plus errors, and an amber light for minus errors. If the indicator shows " no-go " (either plus or minus), the amount of error can be read on the dial gauge. The same gauge can also be used for mechanical reading only, and two tolerance markers are provided for this purpose.

Fractional-Horsepower Packaged Variable-Speed Drive

An inexpensive type of fractional-horsepower packaged variable-speed drive is announced by Heenan & Froude Limited, of Worcester. Designed for use with a.c. mains, this new " Ajusto-Spede " drive, which is made in the U.K. by Heenan & Froude under licence from the Dynamatic Division of the Eaton Corporation, U.S.A., is capable of infinitely variable speeds over a wide range and comprises a fixed-speed single- or three-phase induction motor mounted integrally with an eddy-current variable-speed coupling in one sturdy drip-proof housing. The motor and the coupling input member run at constant speed, whilst the speed of the output member is infinitely variable. A small tachometer generator is built into the housing and the variable-speed shaft extends through the unit so that power is available at either end.

The overall length of the drive unit is approximately 15½ in., the diameter of the housing being about 6½ in. The controller, which is similarly compact, measuring only 5 × 5 × 6½ in., may be mounted remotely from the drive, and comprises a single-valve electronic unit, with colour-coded wiring to facilitate installation. As the amount of controlling current required is very small, low-powered components can be used. The circuit is designed to afford close control of speed, even when there are wide changes in load.

a fine cut

As connoisseurs of fine cutting, we can recommend Jessop-Saville high speed steel butt-welded tools as today's speciality. They permit higher operating speeds and their exceptional hardness qualities enable them to operate for long periods between regrinds. A Stock List giving full details of this Jessop-Saville range is published monthly. Please send for a copy.

JESSOP-SAVILLE

ARKWELD AND TRIUMPHWELD

high speed steel butt-welded tools

WM JESSOP & SONS LTD
BRIGHTSIDE WORKS SHEFFIELD

J J SAVILLE & CO LTD
TRIUMPH WORKS SHEFFIELD

ALL ENQUIRIES TO: SMALL TOOL WORKS PORTLAND ST SHEFFIELD TEL: 20224

P2738

Sintered Alumina Ceramics

A new subsidiary, known as Royal Worcester Industrial Ceramics Ltd., has been created at Tonyrefail, Glamorgan, by Royal Worcester Limited to cater for the production of high-alumina ceramics for use in a wide range of industries.

Designated " Regalox ", these hard ceramics, which have a specific gravity of 3·45, are of high-grade sintered alumina. With a hardness between that of diamond and sapphire, they are unaffected by high working temperatures and remain dimensionally stable under all conditions. Where required, components can be high-temperature-metallized, a process which has already had a wide application in the field of electronics. In addition, they are highly resistant to both mechanical and thermal shock, have a low coefficient of friction, are non-magnetic, are excellent insulators, are impervious to moisture, and withstand the action of practically all chemicals, including molten metal oxides and sulphides.

Linear-Motion Ball Bushings

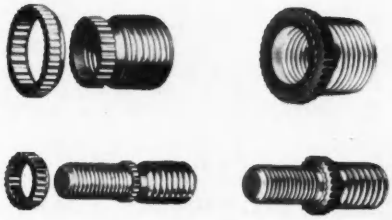
Already widely used in the U.S.A., linear-motion ball bushings are now being manufactured in the U.K. by the Ransome & Marles Bearing Company Limited, of Newark-on-Trent, under licence from the American manufacturers. Designed only for linear motion, these bushings contain three or more ball circuits, around which the balls rotate as in a conventional ball bearing. Some of these balls carry the load in one portion of the circuit, while the unloaded balls continuously recirculate back to the starting point in a retainer. Consequently, they offer all the advantages over plain bearings of effortless rolling motion, as opposed to sliding motion, thereby reducing starting loads, providing limitless length of stroke, and permitting the use of higher speeds.

Each of these ball bushings forms a compact assembly which can be handled as a unit and is as easy to fit as a plain bearing. Their low coefficient of friction is hardly affected by changes in load or lubricant viscosity, and no complicated lubrication systems are required. At present, eleven shaft sizes are available, from $\frac{1}{4}$ to 4 in., with corresponding outside diameters from $\frac{1}{2}$ to 6 in.

Permanently Locked Studs and Inserts

Providing a satisfactory solution to the problems arising from the use of conventional studs and inserts, " Rosan " permanently locked studs and inserts are now manufactured in the U.K. by the Instrument Screw Co. Ltd., of South Harrow, Middlesex, under licence from Rosan Inc., of Newport Beach, Cal. These units, which are similar to conventional threaded studs and inserts, except for the addition of a serrated collar and a lock-ring, are screwed into a prepared hole in the parent metal, the hole being provided with a countersunk neck. The lock-ring is placed over the stud or insert, so that the inner serrations of the ring engage with the serrated collar, and the ring is then driven into the parent metal, its body being accommodated in the countersunk recess at the top of the hole, while its outer teeth, which are undercut to form true broaches, cut their way into the parent metal until the ring is flush with the surface of the metal.

Once secured, the stud or insert becomes part of the parent body, being permanently locked in. Should it become damaged, it is simple to remove and may be replaced with an identical unit. It can, of course, be replaced with a larger unit or a solid unit in the event of design change, wrong positioning or faulty processing, thus saving the scrapping of an otherwise correct and costly component. No special drills, taps, or gauges are required for the preparation of the holes. The inserts and studs themselves are manufactured with a very slightly oversize effective diameter externally, thus ensuring a snug fit. Simple installation wrenches and punches are available for their actual installation, though these are not essential.



The greatest advantages to be derived from the use of these units arise where positive locking is required under conditions of vibration, high stress, and temperature changes, and where frequent assembly and dismantling of a unit is necessary, especially in units of soft material, where thread wear or stripping may result. They are also useful in cases where high torque is required for installation and removal of mating nuts and bolts, and for nuts and bolts that may become rusted, corroded, or mechanically jammed, as removal can be accomplished without disturbing the stud or insert.

Special Cork-Base Gasket Material

A new gasket material, " Uniphase Cork ", developed to eliminate seepage and leakage in applications where neither conventional cork compositions nor cork and rubber have been completely satisfactory, is announced by the Armstrong Cork Co. Ltd., of London, W.C.2. This radically new gasket material is stated to offer the maximum combination of impermeability, resilience, and chemical inertness.

The main feature of the material is its continuous-phase synthetic elastomeric binder, which encloses all the cork particles in a continuous matrix. As a result, the material presents a solid barrier to the passage of fluids or gases. Thus, oil-penetration tests at 212°F at a pressure of 30 psi show that, because of this continuous phase, oil penetration is only one-third that of cork and synthetic rubber gaskets, and one-fifth that of conventional cork composition gaskets.

The material, which is made by a process that retains the natural conformability of cellular cork, forms a positive seal at unit loads as low as 100 psi, where most conventional gaskets fail. The major reason for this is that the elastomeric binder actually conforms directly to the flange surface, completely filling surface imperfections caused by milling or abrading operations. Flange loads as high as 4000 psi will not crush it or cause it to extrude. It seals over a wider range of flange pressures than any other gasket material, and has significantly higher resistance to chemical attack than other similar materials, while its synthetic binder more closely approaches the chemical inertness of cork itself than other materials generally used in gasket compounding. Moreover, it is extremely resistant to fungus growth.

Resistance Heating—1

In this form of heating, the heat is produced by passing an electric current through a high resistance conductor which is termed the "heating element".

The heat is transferred from the heating element to the work by convection, radiation or conduction or by a combination of any, or all, of these. When it is a question of radiation or convection, the element can be a bare wire or strip of suitable material, provided it is adequately supported on electrical insulation capable of withstanding the temperature.

When there is to be contact between the work and the element, heat being transferred to the work by conduction, the wire or strip must be surrounded by suitable insulating material and enclosed in a protective sheath.

In the majority of cases, the wire or strip forming the heating element is made of a nickel-chromium alloy which has a high electrical resistance and can be safely used in air at temperatures of up to 1050°C., or in a suitable atmosphere, of up to 1150°C. Other element materials are available for use at higher temperatures.

Sheathed elements, essential for contact heating but also used widely for convection and radiation heating because of the convenience afforded by the mechanical strength of the sheath, usually metallic, and by their "built-in" electrical insulation, cannot be used at temperatures as high as the bare wire or strip. This is because the wire, being embedded in insulation, is always at a higher temperature than the sheath, and to keep the wire temperature down to a safe figure the sheath temperature is usually limited to a maximum of around 800°C.

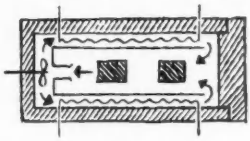
Automatic temperature control of resistance heating elements within narrow limits is easily effected, but if manual control only is desired, devices are available which enable the heat output of the elements to be controlled precisely at a required level. As with all electrical methods, a time switch may be included in the control circuit for automatically switching on or off at predetermined times, and this can enable, for example, an electric oven to be fully up to working temperature by the time the working day starts. Since there are no combustion products from the heaters, there is no need to build flues or special ventilating arrangements which also carry away useful heat.

Electric resistance heating may profitably be put to many diverse uses; two of these are described briefly below, others will be listed in a subsequent data sheet.

Furnace Heating

Electric resistance furnaces can be divided into two main categories, batch type and continuous. In most cases, the heating elements are of nickel-chromium alloy, for furnace temperatures up to about 1050°C., but higher temperatures, up to nearly 3000°C., can be obtained by using other metals or alloys, or in some cases non-metallic elements. A protective atmosphere is desirable to prolong the life of some of these higher-temperature elements. For all temperatures electric resistance furnaces can be constructed so that the heating process takes place in a controlled atmosphere if this is dictated by the composition or heat requirements of the work charge. In some furnaces, fans are used to circulate the air or special atmosphere over the charge, thereby giving increased heating rates and a uniform temperature over the whole charge.

Automatic temperature control and program control of the heating process are readily effected.



Electric furnaces are extensively used in industry, for example in the general heat treatment of metals, in the glass and ceramics industries, for grazing and sintering, and for many other applications requiring temperatures above 500°C.

Oven Heating

There are two basic forms of heat transfer used in electric resistance ovens; convection and radiation. The latter is dealt with in a separate data sheet under the heading "Infra-Red Heating".

Convection ovens may again be of the batch or continuous type. In either case, the charge is heated mainly by the movement of hot air, which is sometimes assisted, as in furnaces, by fans to give a rapid and uniform temperature rise. Ovens are normally designed for temperatures of up to about 500°C., and the heating elements are invariably of nickel-chromium or nickel-chromium-iron alloy.

Ventilation, when required, can be provided and regulated entirely to suit the heating process. Temperatures and times are readily controlled. A vacuum can be maintained in suitably designed ovens to assist in the extraction of moisture and solvent.

Convection ovens are extensively used for drying, baking and stoving operations, and for a host of other processes requiring a low or medium temperature.

For further information, get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, W.C.2.

Excellent reference books on electricity and productivity (8/6 each or 9/- post free) are available—"Resistance Heating" is an example; "Induction and Dielectric Heating" is another.

E.D.A. also have available on free loan a series of films on the industrial use of electricity. Ask for a catalogue.

6780/2A

CUT HERE

ADDITIONAL ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

Machine for Evaluation of High-Temperature Alloys under Combined Static and Dynamic Stresses.

By P. E. HAWKES and C. H. EK. (From *ASTM Bulletin, U.S.A.*, No. 235, January 1959, pp. 46–51, 12 illustrations)

DURING the operation of a gas-turbine engine, turbine buckets are subjected to a static tensile stress, owing to centrifugal forces acting on the bucket and flexural fatigue stresses caused by resonant vibration of the bucket. Because of these conditions, bucket failure may be the result of stress-rupture, fatigue, or a combination of both. For this and other applications, it was considered that there was a need for an elevated-temperature bench test machine capable of evaluating the simultaneous effects of creep loading and flexural fatigue stresses on small specimens of high-temperature alloys.

As a result, a resonance-type of testing machine has been developed to serve as an aid in the development of new high-temperature alloys. The machine subjects the specimen to a static or stress-rupture loading, combined with a high-frequency fluctuating stress, to simulate service loadings typical of highly stressed components, such as gas-turbine buckets, wheel materials, combustion-chamber liners, etc. The test temperature range is from 1000 to 1800°F.

The static (axial) component of stress is obtained through the use of a lever and dead-weight system, while the dynamic stress results from lateral resonant vibration of the vibrating system, composed of the specimen itself, together with the axial loading device chucked to its upper end. The machine is equipped with two servo-systems for automatic control of amplitude of lateral vibration and of temperature at the test section.

A digital programme, which calculates the stresses and vibratory elastic line of a 12-section axially loaded beam, is employed as a convenience in obtaining a stress calibration for the machine under a variety of combined loadings, materials, and temperature distributions.

The results of tests on two high-temperature alloys are included to illustrate the utility of the machine. Data are presented as modified Goodman-type diagrams, as well as three-dimensional diagrams incorporating axes of static loading, dynamic loading, and time.

Voltage Comparator with High-Speed Switches.

By J. W. HIGGINBOTHAM and H. H. DOUGLASS. (From *Electronics, U.S.A.*, Vol. 32, No. 5, January 30, 1959, pp. 56–58, 4 illustrations.)

ANALOGUE applications sometimes require d.c. voltage comparators which are capable of drift-free, low-level error detection and high-speed switching of a load current at a preset magnitude. Conventional carrier-amplifier circuits employ electromechanical choppers to convert d.c. error voltages into suppressed carrier outputs. Such devices limit the carrier frequency to a few kilocycles, restricting the amplifier band-width and response speed.

Transistor choppers, however, operate at up to 50 kcs on a few milliwatts. Square waves to gate these choppers may be supplied from small, inexpensive square-loop-core oscillators, which operate well up to 20 kcs. If higher frequencies are desired, multi-vibrators or oscillators with diode clamping can provide square-wave gating voltages.

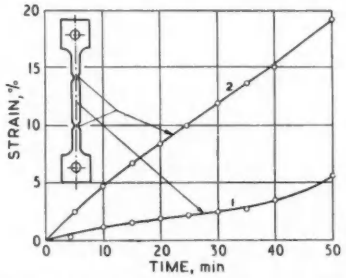
The combination of a transistor oscillator, chopper modulator, and demodulator provides the prime requirements for amplifying direct current with an a.c. amplifier. An a.c. amplifier placed between the modulator and demodulator provides an excellent driftless d.c. amplifier. Since the carrier frequency is high, the band-width is increased; if the a.c. amplifier is made to pass square waves, the filtering required at the output is negligible.

As described in this article, a transistorized unit, which monitors two d.c. voltages continuously, has been developed. In this unit, when the difference between the voltages exceeds the preset threshold voltage, which may be as little as 100 μV for approximately 300 μsec, the output switch latches on, delivering up to 2A to a load. Resetting is accomplished by breaking either the earth or the 28-V supply. Since the individual circuits have been developed in module form, they may be used in many other applications, with little or no modifications. The oscillator chopper module serves as an electronic replacement for electromechanical choppers, where its limits on voltage and impedance levels are not restrictive. The frequency of the unit may be varied over a range from 200 to 20,000 cps by varying the d.c. excitation voltage and the number of turns on the transformer windings. The a.c. amplifier may be used as a gain-stabilized pre-amplifier for servo-systems or voltmeters.

Strain in Technically Pure Iron under Cyclic Temperature Variations.

By M. G. LOZINSKI and I. S. SIMENOVA. (From *Metallovedenie i Obrabotka Metallov, Russia*, No. 1, January 1959, pp. 15–19, 9 illustrations)

IN modern machines and mechanisms, metallic components, operating in high-temperature environments, are frequently subjected to temperature variations which can cause a sharp decrease in their strength. Although, during the operation of many machines, a wide range of temperature changes takes place, their effects have often been neglected in the design of the components concerned. As a result, investigations have been carried out in Russia into the laws governing strain in technically pure iron (0·03% C) under tensile load, with a temperature gradient along the testpiece and with cyclic temperature variations, and have established the existence of a distinctive "super-high" ductility, characterized by the formation of two necks in the testpiece and by rapid shear strain.



Before testing, the testpieces were vacuum-annealed for 2 hr at 1000°C. Miniature flat testpieces were used and were heated by passing a low-voltage mains-frequency current through them, using flexible copper-braid leads to the shackles. The longitudinal temperature range was from about 400°C at the shackles to 800 or 1000°C at the midpoint. With regard to the temperature cycle at the midpoint, the normal cycle included dwell periods of 2 sec at the upper and lower limits, but further tests were

Smooth out the production flow . . .

DORMER

SILVER RING

Regd.

TWIST DRILLS

. . . take the tough jobs in their stride

THE SHEFFIELD TWIST DRILL AND STEEL COMPANY LIMITED

SHEFFIELD ENGLAND

DORMER TOOLS ARE OBTAINABLE FROM YOUR USUAL ENGINEERS' MERCHANTS

carried out with dwells of up to 60 sec. The temperature cycle was automatically controlled. Under certain conditions of cycling, two necks were formed, located symmetrically in the lower temperature zones.

Strain-time curves were plotted, as shown, curve (1) indicating the results for the central zone (800 to 1000°C) and curve (2) for the necking zone (720 to 850°C) under a stress of 0·33 kg/mm². It should be noted that, throughout the test, the overall strain and the strain rate were several times greater in the necking zone than in the hotter central zone.

To study the effect of the upper level of the heating cycle on the position of the necking zone, a series of tests was carried out with the minimum kept at 800°C and the maximum varied from 850 to 1100°C in steps of 50°C. With the upper limit at 850°C, a single neck formed at the midpoint; with the upper limit between 900 and 1100°C, two necks were formed, the distance between them increasing from 14 to 35 mm. The temperature at the necks was always between 720 and 850°C.

Finally, a series of tests with increasing holding times at the upper and lower limits showed that, with a dwell of 10 sec or more, double necking was no longer observed.

The explanation of the formation of two necks is as follows:—With a mean carbon content of 0·03%, the carbon in certain areas (notably at the grain and Bloch boundaries) may considerably exceed this mean, as has been confirmed by experiments on the effect of grain size on carbon solubility and by direct autoradiographic examination, using radiocarbon. Thus, it can be postulated that, when a temperature gradient is set up along the testpiece, the alpha-gamma transformation will occur only in isolated areas of higher carbon content and hence at a lower transformation temperature. This transformation is accompanied by a notable expansion, leading to loss of coherence and to the formation of a large number of dislocations, resulting in a considerable drop in resistance to strain in the affected areas. If, however, the austenite is allowed to remain for appreciable periods, diffusion and relaxation phenomena can repair the structural damage and restore normal strength.

It is pointed out that cases of disastrously rapid strain are not unknown in components subjected to repeated thermal cycling, the necessary conditions being cycling through a definite temperature range (not necessarily the highest the material can withstand), coupled with a strictly limited dwell at the upper and lower cycle limits.

An Experimental Study of Some Variables of the Tube-Expanding Process.

By L. E. CULVER and H. FORD. (From a paper presented at a meeting of *The Institution of Mechanical Engineers London*, February 1959, 13 pages, 9 illustrations)

THIS paper deals with certain aspects of the tube-expanding process, which have been investigated using the test rig previously developed as part of research sponsored by the British Shipbuilding Research Association. The factors investigated are retubing, the starting position of the roller cage within the tube, and the initial clearance between tube and seat. A few tests are also reported on the relaxation of the joint with time.

In the retubing tests, further tubes were expanded into seat plates used in previous tests, from which the original tube had been removed. The main conclusion is that seat pressures can approach the theoretical maximum in retubing, and that, if an extra pass is made to take advantage of the work-hardened seat, a stronger joint than in a first expanding results.

To study the effect of the starting position of the rollers within the joint, four complete tests were made. The results show conclusively that a much stronger joint is obtained with less work, if the rollers start with their front ends almost at the back of the joint.

Tests to study the effect of the initial clearance between tube and seat showed that clearance is not a major factor in joint strength. In fact, the general conclusion is that the effect both of initial clearance between tube and seat and of the amount of tack-rolling is negligible, compared with the accidental variation found between one test and another. A larger clearance causes the tube to be harder at the start of expanding proper and, although this affects the relative tube-plate hardness, its final effect is swamped by other factors. Generally, the average tube hardness is roughly equal to, or slightly less than, the hardness of the seat at the end of expanding, irrespective of the clearance.

It has been stated by some investigators that there is a relaxation of the residual stresses with time, but they made no attempt to assess the effect. During the present series of tests, assemblies were allowed to stand for varying amounts of time after expanding. One assembly stood for 72 hours, while three others were left for 7 days. In no case could any change in the readings, either by the displacement calipers or of the surface strains on the plate, be discerned. These tests may not be decisive, but they are sufficiently good to lead to the conclusion that any relaxation must be very small and will not have affected any of the results in these tests.

Properties of an Electron Beam in the Presence of an Axial Magnetic Field of Arbitrary Strength.

By H. WILHELMSSON. (From *Transactions of Chalmers University of Technology, Gothenburg, Sweden*, No. 205, 1958, 32 pages, 1 illustration)

THE properties of an electron beam in the presence of an axial static magnetic field are of great technical interest, particularly in the construction of microwave tubes and in connection with the work of thermonuclear laboratories. The modern accelerator technique necessitates detailed theoretical studies of the interaction between a beam of charged particles and a.c. electromagnetic fields at relativistic velocities.

The purpose of this paper is to study the effect of an axial magnetic field of arbitrary strength on the propagation of waves in an electron beam. In order to make the beam the simplest possible mathematical idealization of an actual physical beam, two assumptions are made, i.e., (1) the d.c. current density and the d.c. electron density are constant over the beam cross-section and uniform in the axial direction of the beam, and (2) the electron beam is infinitely long and of a cylindrical shape. Furthermore, the small signal theory is used, i.e., all a.c. quantities are assumed to be small in comparison with the corresponding static quantities, thus making non-linear a.c. terms negligible. Collisional effects are also neglected. It should be noted that, although the electrons can oscillate in arbitrary directions, the axial magnetic field affects their oscillations.

Angular asymmetrical modes are also considered in this study, and special attention is paid to the influence of the drift Lorentz terms and of the relativistic corrections. The equation of motion of the electrons and the equation of the continuity has made it possible to calculate the a.c. components of the current density expressed in terms of the components of the electric and magnetic a.c. fields. By introducing the expressions for the a.c. current density into Maxwell's equations, two coupled differential equations are obtained for the axial field components, and the system of these two coupled equations is exactly solved. From the coupled field equations information is gained about the existence of various types of waves available for excitation and also about their interactions.

The wave functions, obtained in solving the coupled field equations, are used to describe the wave-propagation properties of an electron beam of uniform electron density distribution over the whole space inside a perfectly conducting wave-guide. As a result, an equation is obtained for the propagation coefficient of the waves excitable in the beam. This equation, which takes into account the presence of an ionized medium, relativistic corrections, and the possibility of angular asymmetrical excitation, needs further numerical analysis with the aid of an electronic computer. Finally, the coupled field equations are compared with the results of other authors.

THE METEM COMBINE

CONTINUOUS PRINTING AND DEVELOPING IN 1 UNIT

The Metem Combine offers all these advantages:

- ★ Continuous printing and developing—no tracing is too long.
- ★ Full printing width of 46 in.
- ★ Small diameter printing cylinder for perfect contact.
- ★ New features in dry development—no liquid to be changed—little cleaning.
- ★ Receiving trays for both tracings and finished prints.
- ★ Holder for roll material and paper cutting slot in the feed board.
- ★ Simple controls—can be operated entirely from the front.
- ★ Inexpensive robust and compact—occupies only 21 in. × 69 in. of floor area.

costing only

£195

OZALID

STAND NO. 6
Engineering and Marine Exhibition, Olympia, 16th-30th April.

OZALID COMPANY LIMITED, Langston Road, Loughton, Essex. *Telephone : Loughton* 5544.

New Materials, Processes, and Equipment

HIGH-SPEED VERTICAL MILLING MACHINE

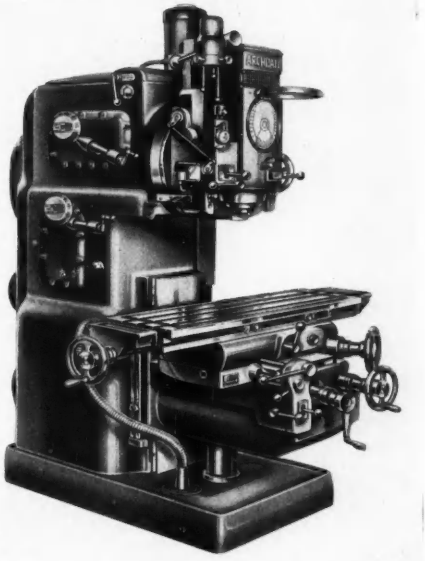
Designed to meet the demand for speed and power and for milling to exceptionally high standards of finish, the No. 2 high-speed vertical milling machine announced by James Archdale & Co. Ltd., of Birmingham 16, covers a wide range of work, including die-sinking, tool-room, and production milling. The cutting capacity of the machine lies generally in the range between $\frac{3}{32}$-in. diameter slot drills, which it will drive safely at traverses 50% above makers' schedule, to tungsten carbide cutters of 7 in. diameter, producing finishes equal to surface grinding, if used with the technique of honing in position.

An unusual feature of the spindle head is the complete frontal control. Adjustment and locking of the inclination of the swivel head and lock of the spindle slide are accomplished by the use of a single box key, and the drawbolt is manipulated by a hand crank. With direct angle reading and finger-tip control levers, change-over is reduced to a fraction of the time hitherto involved. The design of the spindle drive ensures that the offset of the cutter from the vertical centre, when the head is swivelled, is kept to a minimum. The basic principle governing the design of the spindle head lies in the reduction of the number of gear lines between the motor and the spindle. Reduction of gear contacts is necessary to prevent intermittent action of the cutter from accumulated backlash. Thus, a major factor in the spindle drive is the use of a two-speed motor, by means of which a wide range of speeds may be obtained with only two spur-gear contacts, in addition to the final spiral bevel gear on the spindle. The motor is continuously rated at 4/8 hp, giving synchronous speeds of 1000 and 3000 rpm respectively.

There are only two lines in the drive (apart from the spindle line), and these can be produced with extreme accuracy for centre distance and parallelism, permitting the use of profile-ground gears with minimum backlash. The final drive to the spiral bevel shaft for the four highest in each range of twelve speeds is by wide constant-mesh single helical gears. Additionally, the pulley is run at 1800 rpm in the upper range speeds. This imparts a momentum to the gears which, in conjunction with the general avoidance of clearances in the spindle drive, does away with the necessity for a flywheel when using a tungsten carbide cutter.

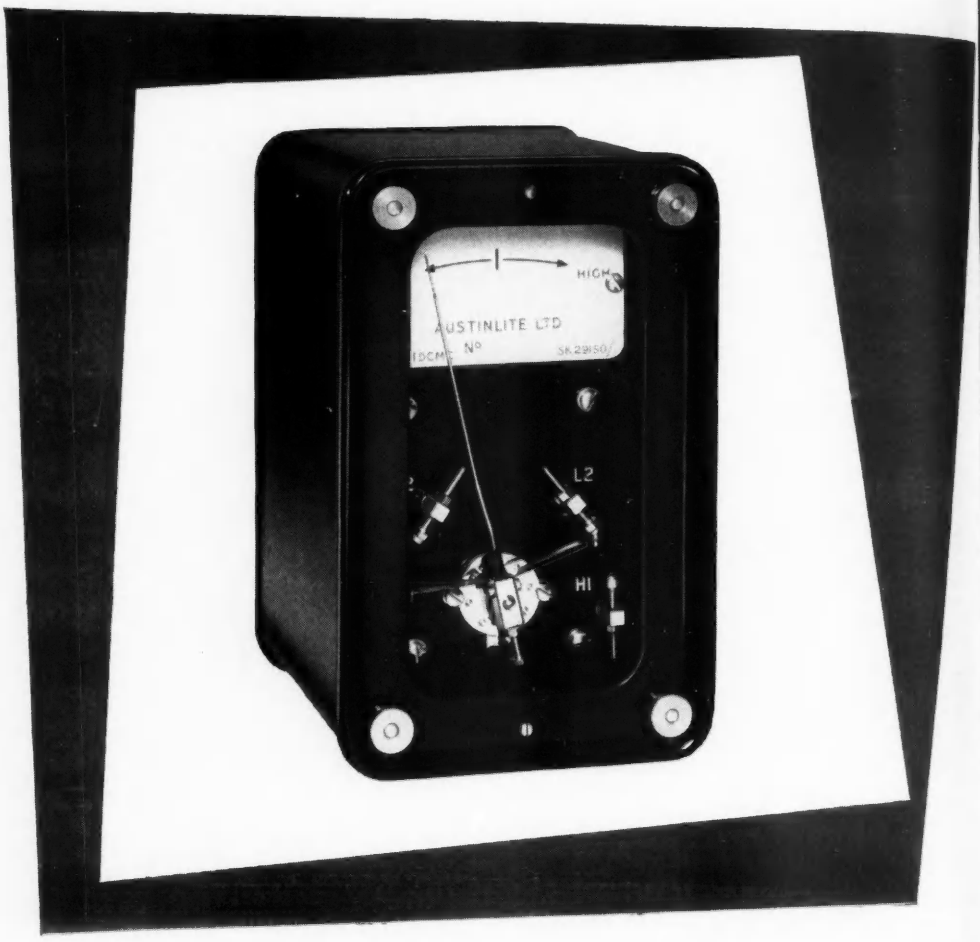
The spindle head is a self-contained unit incorporating its own feeds and rapid traverse to the spindle slide. The drive is taken from the two-speed motor by a belt to the driven pulley, which connects to the spindle gear-train by a single dry-plate Ferodo-lined electromagnetic clutch and brake, with a rated capacity of 18 hp at 1800 rpm. Control of the clutch is by a lever at the front of the spindle head, positioned positively by spring loading in the " off " position; " pull " and " up " starts the spindle, while " pull " and " down " engages mechanically the draw-bar to the hand crank immediately adjacent. This gives an interlocked arrangement which permits safe and rapid changing of cutter adaptors from an accessible position. The spindle feed is taken from the drive, as in a drilling or boring machine, and gives three rates of feed per revolution. Constant-rate rapid traverse is provided by a separate motor. The lever which controls these motions is mounted at the front of the swivel head and is positioned by spring loading in the " neutral " position, from which point " pull " and " up " gives " up " feed; additional " pull " gives rapid traverse " up ". These traverses are reversed when the direction of the lever is in the " down " position.

The locking lever for the sliding head is interlocked with the feed lever to prevent feed or rapid traverse engagement when the sliding head is locked At the right front. of the swivel head is a hand-wheel, with a micrometer dial for fine adjustments. Turret stops declutch the down feed and also give dial-gauge readings. For accurate placing, final adjustment with the hand-wheel may be necessary. The adjustable turret stops are arranged with release nuts, so that they may be positioned approximately prior to screwing and locking at the exact setting. The head swivels 90 deg. each way, and is locked by four hexagon nuts accessible at the front. A similar hexagon-headed shaft, also at the front, is used for swivelling the block. The angle of inclination can either be read off divisions on the swivel head or off the clinometer scale.



Gear-changing is effected by a single crank situated in a forward position and is facilitated by a switch which gives a momentary impulse to the clutch as the gears are about to re-engage. From the feed gears in the column, an exclusive type of universal joint is used to transmit the drive to the knee. Each joint consists of drop-forged spiders carrying four standard ball bearings. These are mounted on shafts totally enclosed, the whole running in continuous lubrication from the oil pump which supplies oil to the speed and feed gears. The advantage of this type of drive is that the spindle and feed are driven from a common source, and that a simplified type of knee is possible, with solid flat-top and deep Vees, producing correct alignments and easy operation.

The lock between the knee and the column and the locking handle for the cross-traverse motion are at the front of the knee, and both are interlocked with the selector level. To accommodate work of a wide nature, the table is of the platform type. The table, cross, and vertical spindle traverse screws are provided with twin nuts with backlash elimination. A " crash-plate " at the rear of the knee protects the cross-feed mechanism, should an obstruction occur between the rear of the saddle and the knee flange.



The Austinlite marginal relay

Here is one of the most sensitive instruments of its kind on the market. Its performance is due largely to the powerful heavy duty Alcomax magnet which ensures positive contact. Made to an exacting specification, this high-torque moving coil relay will respond to changes of 1 per cent in AC or DC voltage or current, and is adjustable between ±1 per cent and ±10 per cent.

This relay was developed for use in Austinlite Control Cubicles, as supplied to the G.P.O. and other telephone authorities throughout the world.

Austinlite

ELECTRICAL EQUIPMENT

Tailor-made by

STONE-CHANCE LTD.

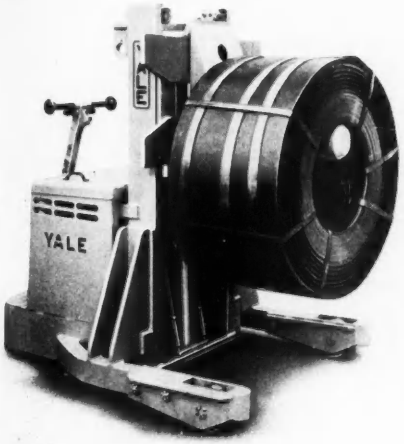
(Makers of Sumo Pumps and Stone-Chance Lighthouses).

CRAWLEY, SUSSEX.

ELECTRIC TRUCK FOR PRESS TOOLS OR STRIP-METAL COILS

Pedestrian-controlled and fitted with heavy-duty straddle legs, a new " Worksaver " truck announced by the Yale & Towne Manufacturing Company, of Wednesfield, Wolverhampton, Staffs., can operate in spaces which are too restricted to permit manoeuvring of counterweighted trucks and can be used for handling press tolls or coils of strip metal up to 5 ft in diameter and 20 in. in width.

A variety of specially designed attachments can be supplied for the truck. Thus, for coil handling, a ram (as illustrated), or a pair of forks, shaped to minimize damage to coils, can be used. A semicircular ram would be fitted to permit coils to be directly removed from coil-winding machines. A solid platform or a pair of forks can be used to handle press tools in circumstances where the use of a die-handling truck or large fork truck would not be practicable, owing to space limitations or cost.

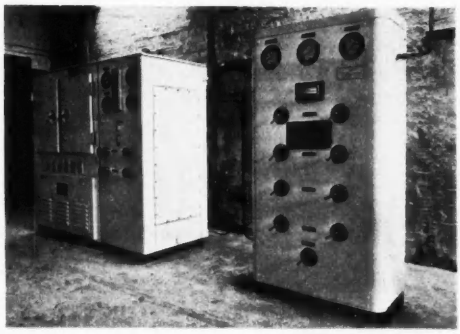


Equipped with fixed, upright mast channels of similar design to those used in Yale Series 51 fork trucks, coils can be lifted to a height of 64 in. by a truck having an overall height of 90 in. Like all " Worksaver " trucks, travel and lifting controls are conveniently placed on the steering handle. Operation is simple, and special truck operators are not required.

SMALL PLANTS FOR LIQUID OR GASEOUS NITROGEN

Designed to produce nitrogen of up to 99·9% purity by the liquefaction and fractional distillation of air, a new range of small, compact, and completely self-contained nitrogen plants, developed by the Refinery & Speciality Co. Ltd., of Eccles, Lancs., to the design of H. E. Charlton Engineers Ltd., is available in five models, with capacities from 1·5 to 24 litres per hour of liquid nitrogen, or from 2 to 30 standard cubic metres per hour of gaseous nitrogen. By virtue of their size, weight, and capacity, these units are particularly suitable for use in tropical and isolated areas where supplies of nitrogen are not readily available from other sources.

The plant basically comprises four principal sections, which fulfil the respective functions of initially compressing the air, removing carbon dioxide, drying, and condensing and subsequently separating the nitrogen by fractional distillation. The use of regenerative driers, a caustic-soda scrubber, and cross counter-current heat exchangers ensures long, trouble-free runs. The drying and separation sections are each housed in neat cabinets,

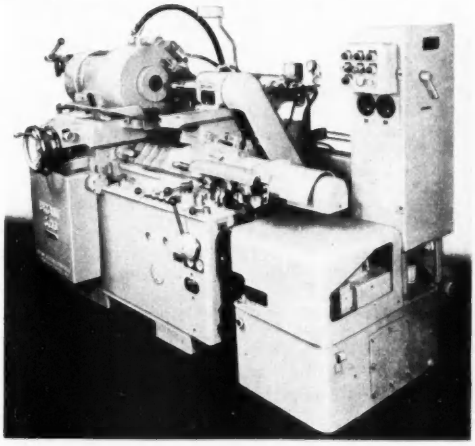


as shown in the illustration, and the plant is supplied fully instrumented and wired up electrically, ready for connection to electricity supply cables. Foundations are required for the high-pressure multi-stage compressor and for the caustic-soda scrubbing tower, but these units can be housed in positions remote from the other two sections.

AUTOMATIC HYDRAULIC INTERNAL GRINDING MACHINE

The new model 3216 internal grinding machine developed by The Bryant Chucking Grinder Company, of Springfield, Vermont, has all machine motions hydraulically actuated, while closely grouped convenient manual controls make the machine suitable for either high-production semi-automatic operation or tool-room work. Attached to the machine, which can be used for both straight and tapered bore grinding, is a special panel which shows the operation of the cross-slide and of the automatic controls, and the functioning of the machine throughout the entire working cycle, which can be easily adjusted for various work sizes.

By virtue of its three-point suspension and the provision of suitable adjustments, the wheel-slide and work-slide are held in perfect alignment. The work-table moves on two parallel anti-friction bearings, which are spaced to give wide support, a shoe riding on a flat plate offering a third support point. The cross-slide is designed to ensure precise and smooth work-table response to the slightest movement of the feed-screw; for this reason, it is located below the work-head, providing a wider control base than would be possible if it were located beneath the wheel-head. The machine can swing 16 in., permitting the grinding of straight and tapered holes to a



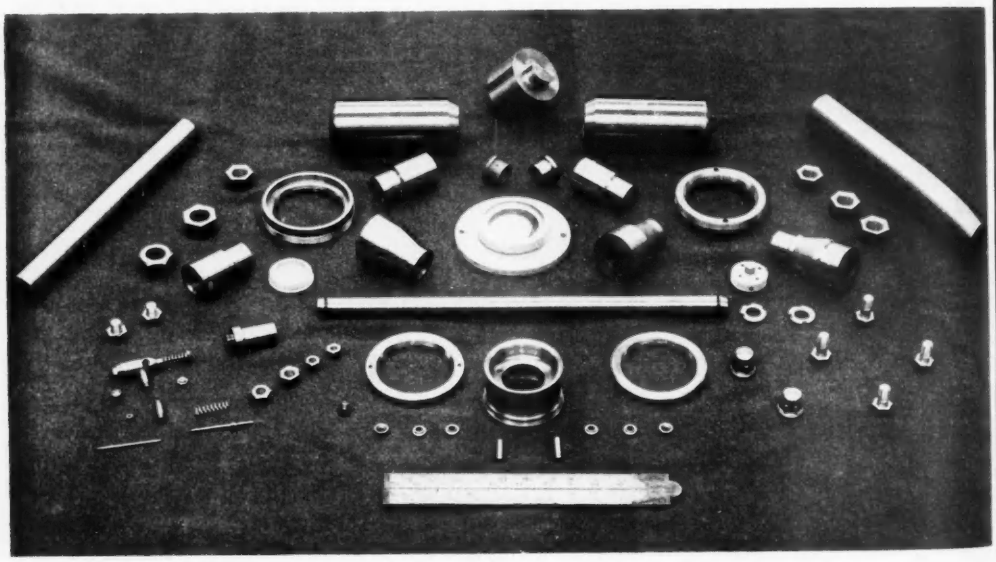
Machining Capacity for Small and Intricate Components

of all sizes and quantities, is often sought by Manufacturers with an urgent or continuous delivery problem.

Hadfields are specially equipped to handle such work and the help they can give covers additional range, because the machine tools in question are suitable for Special Steels which are normally difficult to machine.

The Machine Tools available include Capstan Lathes for bar work up to $2\frac{1}{16}$" diameter and chucking work up to $9\frac{1}{2}$" diameter.

A comprehensive and reliable service is offered with an assurance of sound workmanship.



HADFIELDS
SHEFFIELD

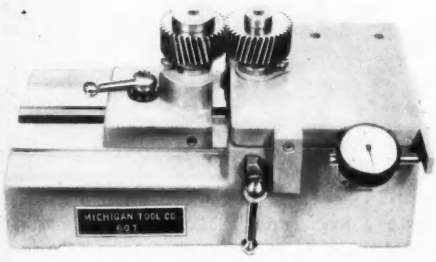
HADFIELDS LTD., EAST HECLA WORKS, SHEFFIELD, ENGLAND

depth of 9 in. with a plain work-spindle, or 8 in. with a cam-lock spindle.

The machine is equipped with Bryant " Air-Sizing " equipment for the automatic size control of bores, enabling grinding and sizing of bores to be performed to extremely close tolerances and eliminating the need for hand-gauging and manual operation of any kind. This equipment utilizes three main components, i.e., an air plug, an air-gauge panel, and an impulse timer. The air plug is mounted through the work-head and traverses continuously into the workpiece during the finish-grinding cycle, oscillation being timed and controlled from the wheel-slide. The air-gauge panel measures the pressure peaks occurring at the air-plug orifices each time the air plug enters the workpiece. These pressure peaks are multiplied to make gauging faster and more sensitive, and are then converted from pressure values into electrical impulses for operating the impulse timer, which continues the grinding cycle until the impulse signals stop, indicating that size has been reached. It then stops the grinding cycle and initiates the loading cycle.

PRECISION BENCH-TYPE GEAR-ROLLING FIXTURE

A new bench-type gear-rolling fixture, for accurately checking external spur and helical gears and covering the most-used range of gear sizes, has been developed by the Michigan Tool Company of Detroit, Mich. The fixture, designated model 607, will check the size, eccentricity, and meshing smoothness of external spur and helical gears up to 10 in. in diameter. This is effected by manually rotating the gear to be checked against a master gear, all deflections being shown on an integrated dial indicator in increments of 0·0005 in. The master-gear assembly is spring-loaded, and rides on hardened and ground ball-bearing ways. A hand-actuated cam disengages the meshing action and permits easy removal of the gear from the fixture.

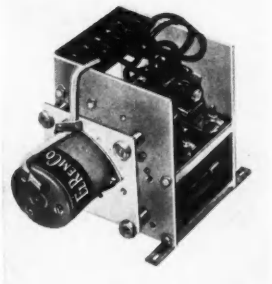


A particular feature of the fixture, which measures only $7 \times 15 \times 5\frac{3}{4}$ in. high, is the use of a replaceable precision bushing on the master-gear and part stud. Master-gear rotation can be in the bore of the master or in the bushing, greatly extending the service life of the equipment. Centre distance is adjustable from $1\frac{3}{4}$ to 6 in.

MULTI-CIRCUIT MERCURY-SWITCH TIMERS

Driven either by a miniature synchronous motor or by a universal motor for a.c. or d.c. operation, a new range of heavy-duty multi-circuit timers introduced by the Electrical Remote Control Co. Ltd., of Harlow New Town, Essex, uses a number of tilting mercury tubes or switches operated by a camshaft. The motor gears are easily interchangeable, providing alternative speeds for the camshaft between one revolution per second and one revolution per 28 days. These timers are capable of continuously repeating a predetermined sequence of operations, or they can stop after a single complete timing cycle if one of the mercury switches is wired in series with the motor.

Single-pole or change-over mercury tubes, with switching capacities from 5 to 30 A, are fitted as standard. If the tube has to perform a switching action several times during a timing cycle, the operating cams are precut in accordance with requirements; if the tube has to operate only once during a cycle, continuously adjustable cams are supplied. Any number of cams and switches can be



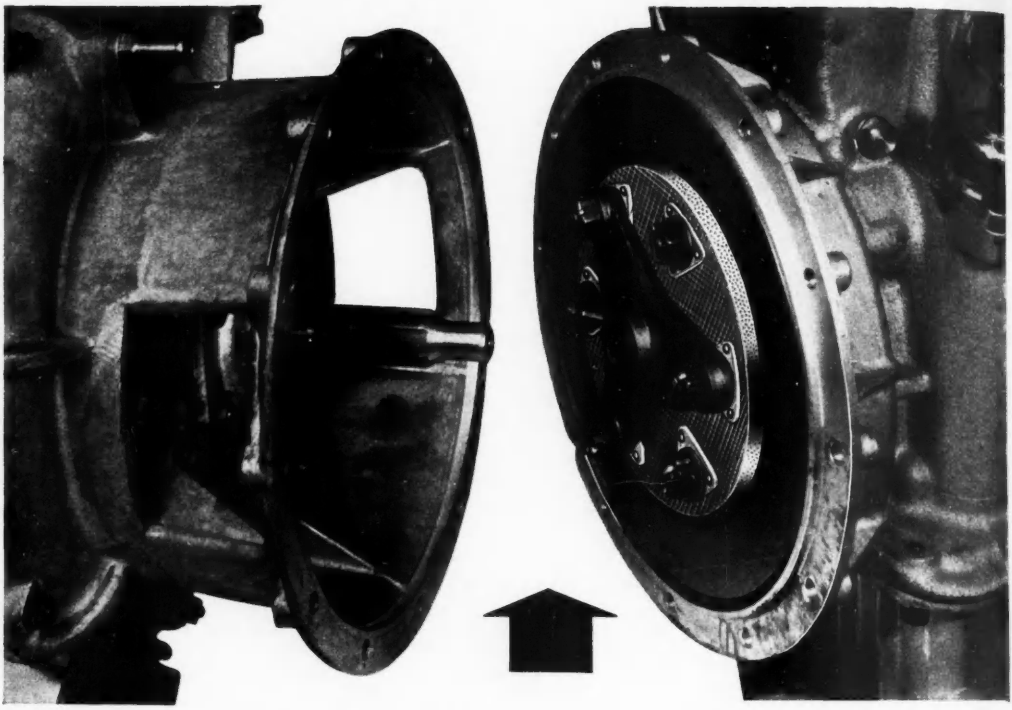
fitted but, where units with more than 24 cams are required, two or more timing shafts, driven from a common motor, are used. For timing cycles of more than 30 sec duration, the switches are mounted on tilting platforms with a snap-action mechanism; for faster timing cycles, the cams operate the platforms directly. The units can be supplied either unmounted or in sheet-metal or flame-proof enclosures.

DRAUGHTING INSTRUMENT FOR EXTENSIVE RADII

Designed to estimate and produce accurate arcs of extensive radii from 4 to 240 ft in a matter of seconds, thereby eliminating time-consuming calculations and plotting out, the " Arcrola " draughting instrument produced by Triangle Products Ltd., of Hyde, Cheshire, is suitable for use in most drawing offices, but more particularly for constructional, aero-engineering, ship-building, and architectural applications.

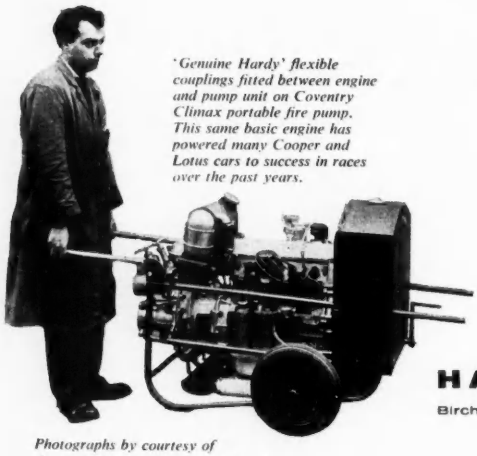
Basically, the instrument consists of a graduated telescopic tube, fitted at one end with a disc and pencil-holder, and at the other with a holder for mounting one of a series of five master discs for different radius ranges, i.e., 8 to 16 ft, 16 to 31 ft, 31 to 61 ft, 61 to 120 ft, and 120 to 241 ft. If no master disc is used, the instrument caters for radii from 4 to 8 ft. As an example of the simple and rapid procedure involved, suppose that an arc with a radius of 221 ft 4 in. is required. All that is necessary is to fit the appropriate master disc, i.e., 120 to 241 ft in this case, and then to set the telescopic scale on the tube to the graduation marked 221 ft 4 in. and to lock it in

position with a knurled screw. The two discs are then placed on the radius line and the weight-loaded pencil is positioned. The instrument is now rolled gently forward, producing a clearly drawn arc of any length, including a complete circle. As the weight-loaded pencil holder moves freely on a ball-bearing mount, the instrument can be used on any reasonable surface.



"GENUINE HARDY" COUPLINGS

* no lubrication * perfectly silent * no wearing parts



'Genuine Hardy' flexible couplings fitted between engine and pump unit on Coventry Climax portable fire pump. This same basic engine has powered many Cooper and Lotus cars to success in races over the past years.

Photographs by courtesy of Coventry Climax Engines Limited.

The 'Genuine Hardy' is not just another flexible disc. It looks like an ordinary disc but its construction is unique. Every layer of fabric on a 'Genuine Hardy' disc is *staggered*. As a result the threads of the various layers run in all directions and consequently the tensile strength of the fabric between each pair of bolt holes is identical. Thus the disc is equally strong all round. No weak points, so no uneven stretching and subsequent vibration. That's why 'Genuine Hardy' flexible discs last years longer. Make sure *you* get 'Genuine Hardy' couplings. Write for full details of the very wide range available.

HARDY SPICER LIMITED

Birch Road · Witton · Birmingham 6 · Telephone: Birchfields 4504-9

product of the **Birfield Group**

Automotive Division of BIRFIELD INDUSTRIES LIMITED · Stratford House · W.1

NEWS OF THE MONTH

PERSONAL

Aero Controls Limited announce the appointment of **Mr. W. H. Haydon-Soutar, A.M.I.Mech.E., A.F.R.Ae.S.,** as chief engineer.

Following the retirement on medical grounds of **Mr. J. Horridge,** George Kent Ltd. have appointed **Mr. J. F. Willsher** as general works manager.

Mr. C. B. Evans has been appointed to the board of Midland Silicones Limited.

Mr. W. L. Valenta has been appointed sales development engineer of the Workington Iron and Steel Company, a branch of The United Steel Companies Limited.

Mr. H. G. Stage and **Mr. F. Tompkins** have been appointed directors of Nu-Swift Ltd., of Elland, Yorks.

Mr. G. R. Bell has been appointed general manager of the British Branch of Wall Colmonoy (Canada) Ltd., and will be responsible for the company's entire European operations.

Mr. John Sim has been appointed general manager of Westool Limited, of St. Helen's Auckland.

Mr. E. W. M. Fawcett, technical director, and **Mr. H. P. P. Hedgkins,** commercial director, of Howards of Ilford Ltd., have been appointed to the board of the parent company, Howards & Sons Ltd.

Mr. James D. Furse has been appointed manager of the refrigeration department of W. J. Furse & Co. Limited, following the death of the previous manager, **Mr. John French.**

Mr. S. Watts has been appointed chief engineer of the contracts division and **Mr. B. Scott-Garrett** chief engineer of the control division of Sir W. H. Bailey & Co. Ltd.

Mr. F. W. H. Shaw has been appointed deputy managing director of Submarine Cables Limited.

Head Wrightson & Co. Ltd. announce that **Mr. George Taylor** and **Mr. John D. Eccles** have been appointed directors of Head Wrightson Steel Foundries Ltd., **Mr. Roger B. W. Bolland** a director of Head Wrightson Colliery Engineering Ltd., and **Mr. Richard O'Brien, D.S.O., M.C.,** a director of Head Wrightson Stockton Forge Ltd.

Mr. A. E. Morton has been appointed sales promotion manager of the recently formed Matbro group of companies.

Mr. George A. Williamson, M.I.Mech.E., director of engineering of the Firestone Tyre & Rubber Co., Ltd., has retired after 31 years service with the company.

Mr. A. E. Gregg, Assoc.M.C.T., A.I.E.E., has been appointed general manager of F. & A. Parkinson Ltd., of Guiseley, one of the companies in the Crompton Parkinson group. Mr. Gregg was formerly product manager for motors, and is succeeded by **Mr. J. C. Mansfield, B.A.**

Mr. R. F. Hunt, A.F.R.Ae.S., A.F.C.A.I., a director of Dowty Group Limited, has been elected deputy chairman of the company.

The British Engineers Small Tools & Equipment Co. Ltd. announce that **Lt.-Col. T. Child, T.D., B.Sc., M.I.Mech.E.,** has relinquished his position of director and chief executive after nine years' service, and that **Mr. Mark H. Taylor, M.I.Mech.E., M.I.P.E.,** is rejoining the board, while **Mr. Arthur Child, T.D., B.Com., A.C.A.,** the present secretary, is also acting manager of the company.

After nearly 47 years service with The British Thomson-Houston Co. Ltd., **Mr. C. H. Chaplain,** manager of the publicity department, has retired. He is succeeded by **Mr. H. G. Harlow,** who has been manager of the BTH Newcastle district office.

Mr. M. Soffa, A.S.M.A., general manager, has been appointed to the board of Jeltek Limited.

OBITUARY

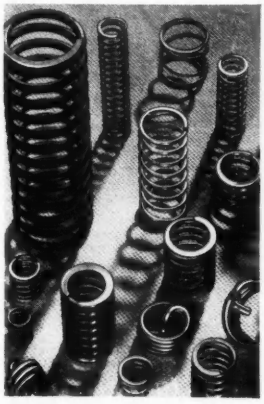
It is with profound regret that we announce the following deaths:—

Mr. H. F. J. Bailey, sales and publicity manager of Edgar Vaughan & Co., Birmingham, on February 4, at the age of 71. Mr. Bailey, who was in the company's service for 34 years, was well known and highly respected in the machine tool and engineering industries.

Dr. Marcel Ballay, president and managing director of the Centre d'Information du Nickel, Paris, on February 2, at the age of 63.

Dr. Luigi Emanueli, vice-president of Pirelli S.p.A. and a director of Pirelli-General Cable Works Limited, on February 16, at the age of 76.

Mr. W. J. Picken, O.B.E., M.I.E.E., technical consultant of The English Electric Valve Company Ltd., on February 24, at the age of 72.



Where MAXIMUM RESISTANCE to HEAT, Fatigue and Corrosion is vital . . .

The design and manufacture of high duty helical, compression, extension and torsion springs possessing exceptional resistance to heat, fatigue and corrosion is the particular speciality of the Lewis Spring organisation. Coil springs can be made in stainless steels (18/8 Austenitic), high nickel alloys (Inconel), Copper Alloys (Beryllium Copper), Alloy Steels (Chrome Vanadium), Molybdenum and plain carbon steels.

Why not call us in *at the beginning* of your next project? You'll be surprised at the number of technical headaches we can help you to avoid.

Send 2/6 postal order for our 40 page booklet on spring design with full technical data. It is an invaluable reference for your design department.

THE LEWIS SPRING CO., LTD.
RESILIENT WORKS, REDDITCH
London Office:
122 High Holborn, W.C.1.

LEAVE IT TO Lewis OF REDDITCH

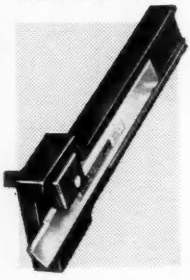
Eclipse TOOL HOLDERS with precision features

Right-hand tool holder

Straight tool holder

Left-hand tool holder

American type for slotted pillar tool post



Cutting off tool holder

use them with

ECLIPSE TOOL BITS to make the perfect cutting combination

. . . . . No ordinary tool holders, these! They have patented clamps with sideways and downwards pressure for the firmest grip. The tool seating is precision machined and openly accessible for easy cleaning, thus giving perfect tool seating and eliminating vibration which may lead to "chatter". "ECLIPSE" are precision holders for precision work and with "ECLIPSE" Tool bits they offer the finest combination for speedy and accurate production.

Made by James Neill & Co. (Sheffield) Ltd., and obtainable from all tool distributors

BUSINESS NOTES

Newton Victor Ltd., of London, W.C.2, the X-ray department of **Metropolitan-Vickers Electrical Co. Ltd.,** have recently introduced a new service to industry in the form of specialized brazing. This service is being provided at the department's Finchley works, where specialized brazing plant is already used in the manufacture of X-ray tubes and valves.

Lang Pneumatic Ltd. announce that they have moved to new premises at Owen Road, Wolverhampton (Tel: Wolverhampton 25221–2–3).

Tecalemit Limited have purchased half the ordinary shares of **British Filters Limited,** of Maidenhead. Mr. S. G. Gates, C.B.E., chairman, and Mr. P. R. Scutt, managing director, of Tecalemit Limited, will join the board of British Filters; Mr. T. E. Worth, B.A., M.I.Mech.E., present chairman and technical director, will continue in that capacity, and Mr. Nigel J. Bennett, D.F.C., A.C.A., will continue as managing director.

Expandite Limited celebrated their silver jubilee on February 24, 1959. The company was founded by Mr. Bertram Watson, who is now chairman and managing director. Expandite Limited is represented throughout the world by its subsidiary companies and distributors, which include **Secomastic Limited** and **Philplug Limited.**

Marryat & Scott Ltd. have acquired the whole of the share capital of **Austin Lifts Ltd.,** of Newcastle-on-Tyne.

Hadfields Limited announce that their home-sales representatives are to act on behalf of the Hadfields Group of Companies as a whole, including **Millspaugh Limited** and their subsidiaries. This arrangement does not include Millspaugh pulp and paper-making machinery or the plant for paper-making works erected by Millspaugh-Wimpey.

Taylor, Taylor & Hobson, of Leicester, held a private exhibition and demonstration of their complete range of measuring instruments, machines, and accessories at the Cheetham Public Hall, Cheetham Hill Road, Manchester, from March 16 to 21.

Hayes Engineers (Leeds) Ltd. demonstrated their new "Tracemaster" automatic copy-milling machine and their "Diemaster" universal die and mould milling machine at the Birmingham Engineering Centre, Stephenson Place, Birmingham 2, from March 16 to 20. Toolmaking firms were invited to discuss technical matters and to bring any job they wished to have demonstrated on the new machines.

Small & Parkes Ltd. announce that their London sales offices and Wimbledon depot have moved to 251 Kingston Road, London, S.W.19 (Tel: CHErrywood 3806/7), and their Chester depot has moved to 86 Watergate Street, Chester (Tel: Chester 21280).

The British and American shares of **British MonoRail Ltd.** have been acquired by **Herbert Morris Ltd.,** of Loughborough. Mr. Frank Morris, chairman of Herbert Morris Ltd., has been appointed chairman of British MonoRail Ltd. Mr. E. Russell and Mr. G. Randsley, of the board of Herbert Morris Ltd., have also been appointed directors of British MonoRail Ltd. Mr. James Dallas will continue as managing director.

Metal Industries Limited have formed a new company, **Brookhirst Igranic (Europe) Limited,** with headquarters in Brussels (62 rue Joseph II), to co-ordinate the European activities of their electrical subsidiary, **Brookhirst Igranic Limited.** Directors of the new company are Mr. John Black (chairman), Mr. H. Derboven (deputy chairman), Mr. R. H. Frings, and Mr. H. O. Houchen.

Simmonds Aerocessories Ltd., a member of the **Firth Cleveland Group,** announce the formation in Belgium of **Simmonds Aerocessories (Belgium) S.A.,** as a subsidiary company, with offices at 25 rue Faider, Brussels.

Advance Motor Supplies Limited have opened a new branch at 96 Duke Street, Liverpool 1, to be managed by Mr. J. G. Lyons.

The London office of **CVA Small Tools Ltd.,** whose head office is at Garantools House, Portland Road, Hove 3, has been moved to 48 High Street, Edgware (Tel: EDGware 4488).

CONFERENCES AND EXHIBITIONS

A convention will be arranged by The British Institution of Radio Engineers on television engineering in science, industry, and broadcasting at the University of Cambridge, from July 1 to 5.

More than 300 exhibitors will show their equipment relating to materials handling, ventilation and air conditioning, heat and sound insulation, product-finishing, and instrumentation at the Factory Equipment Exhibition, to be held at Earls Court, London, April 7 to 17.

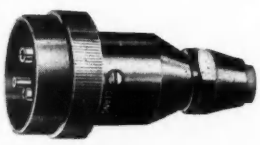
A one day conference on "Noise in Industry" will be opened by the Rt. Hon. Hilary A. Marquand, M.A., D.Sc., M.P., at Earls Court, on April 10, at 10.15 a.m.

Nineteen papers by British authors will be presented at the Fourth International Congress on Electro-Heat, to be held at Stresa, Italy, from May 25 to 29. Altogether, 199 papers will be given in the ten sections into which the congress will be divided.

It is announced that the next Mechanical Handling Exhibition and Materials Handling Convention will be held at Earls Court, London, from May 3 to 13, 1960.

The spring meeting of the Institute of Welding will be held during the Engineering, Marine, Welding, and Nuclear Energy Exhibition to be held in April at Olympia, London. Several works visits and technical sessions are included in the programme.

WEATHERPROOF ACCESSORIES



A RANGE OF PLUGS AND SOCKETS FOR USE WHEREVER A MORE ROBUST AND STURDY TYPE OF ELECTRICAL CONNECTION IS NECESSARY.

ILLUSTRATED CATALOGUE ON REQUEST.

CLANG Ltd. CRICKLEWOOD, LONDON, N.W.2
GLADSTONE 4201 (5 lines)

Another Carter Hydraulic Variable Speed Drive

Carter Hydraulic Variable Speed Drive to Hopper Feeder, built by Richard Sutcliffe Ltd.

Stepless speed variation from input speed down to zero r.p.m. with sensitive accurate control by Hand-wheel, Remote Electrical or Lever arrangements.

Carter Gears may be used to pick up loads from zero r.p.m. and the speed control setting may be adjusted with the drive running or stationary.

Ten sizes for fractional up to 35 horsepower drives.

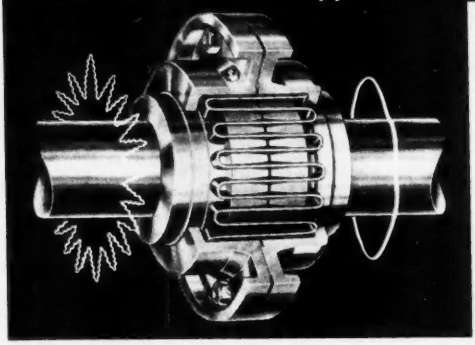
Write for Folder 559.

Carter Gears Limited

BRADFORD 3
YORKSHIRE
ENGLAND

'phone: Bradford 64378 (3 lines)
'grams: 'Became' Bradford Telex

The most efficient coupling obtainable



Over 30 years trouble-free service is normal with

The BIBBY Resilient COUPLING

Breakdowns, heavy production losses, and high maintenance costs are reduced to a minimum. Maximum outputs are ensured.

The unique resilience of Bibby Couplings protects and lengthens the life of machinery by absorbing shocks and vibrations, and accommodating unavoidable angular and parallel misalignments.

There is a Bibby Resilient Coupling for every drive.

We invite you to write, today, for our illustrated brochure.

THE WELLMAN BIBBY COMPANY LIMITED, PARNELL HOUSE, WILTON ROAD, LONDON, S.W.1

CONTRACTS

Ghana Posts and Telegraph Department has placed contracts with Siemens Edison Swan Ltd., for multi-channel carrier equipment to extend facilities for making telephone calls over radio links.

The Union Carriage and Wagon Co. (Pty.) Ltd., a recently established associate company of Leyland Motors Ltd., has obtained one of the largest orders yet placed by South African Railways for locally manufactured goods, representing a contract worth £5,000,000 for 322 all-metal main-line coaches.

A Ferranti high-speed " Mercury " electronic digital computer, valued at about £150,000, has been purchased by the University of Buenos Aires, Argentina.

The British Transport Commission has appointed Crompton Parkinson Ltd. as main contractors for the power equipment of 137 " Type 4 " main-line diesel electric locomotives for use on the London Midland Region of British Railways.

Following the recent announcement by London Transport of orders placed in connection with new underground-railway rolling stock for the Central Line, The British Thomson-Houston Company now has orders in hand for over 850 items of traction-control equipment for London's new underground trains.

The Japan Atomic Power Company announce that they have now opened exclusive negotiations with The General Electric Co. Ltd., of England, for the supply of a 150-MW nuclear power station. It is anticipated that a letter of intent will be placed with the G.E.C. if these negotiations are satisfactory. As already known, the G.E.C.-Simon-Carves atomic energy group are one of the three British groups who have tendered for this station.

NEW ITALIAN MILLS FOR SEAMLESS STEEL TUBES

The construction of a new continuous rolling mill for the production of seamless steel tubes has been completed in Italy at the works of Dalmine S.p.A., of Costa Volpino, by Innocenti, of Milan. The design of the rolling mill follows the concepts of American installations for large-scale standardized production, and it is reported that erection of a second mill will start in the near future, extending the annual production to 150,000 tons of seamless steel tubes.

NEW STEEL AND WIRE ANNEALING FURNACES

After extending their special electric-steel capacity and installing an 800-ton press, a 14-in. three-high mill, a 10½-in. double-duo mill, and new centreless-grinding and wire-drawing machines, Kayser, Ellison & Co. Ltd., of Sheffield, have built in their wire department six vertical pit-type furnaces for annealing and normalizing drawn wire and wire rods and have erected a new annealing plant for their steel department, comprising four town-gas-fired car-type furnaces, each of six tons capacity. In these new installations, close control over temperatures and pressures and good ventilation and fume-removal facilities are provided.

BULK PRODUCTION OF SILICON IN BRITAIN

A large-scale development plant for the manufacture of high-quality silicon of semiconductor grade has been brought into operation by the General Chemicals Division of I.C.I., on Merseyside. The capacity of the plant will approach 4000 lb per annum by the middle of the year, but plans for much larger production are also well advanced. I.C.I. can now supply this material, which hitherto was mainly imported from the U.S.A. and France, both in lump form for crystal-pulling and in rod form for zone-refining.

DIAMOND JUBILEE OF CHARLES BAYNES LTD.

To celebrate their Diamond Jubilee, Charles Baynes Limited, of Knuzden Brook, Blackburn, have issued a brochure covering the history and activities of the firm during sixty years of hacksaw making. In fact, it is especially worthy of note that the hacksaw blades made in the early part of 1898 by the founder of the firm, Dr. Charles Baynes, are probably the first ever to have been manufactured in Great Britain.

The development of the company to its present status makes interesting reading, and there can be no doubt that it is a far cry from those early days when Charles Baynes experimented painstakingly to produce a successful blade, using a converted wash-boiler for his hardening process, to the present automatic production line, in which each individual "Ding-Dong" blade is inspected at least twelve times during manufacture to ensure its soundness of quality.

NEW OIL-STORAGE TERMINAL AT ELLESMERE PORT

A new ocean-fed terminal, costing over £1,000,000, is being built by Mobil Oil Company Ltd. at Ellesmere Port in Cheshire, and will provide facilities for the storage and distribution of a full range of petroleum products. It is hoped to have the installation completed by the autumn.

Classified Advertisements

The rate for all classified advertisements is 9d. per word : in bold print 1s. per word : minimum order 10s. Box-number advertisements 1s. extra. Semi-displayed advertisements on this page 60s. per single column inch. Instructions, together with remittance, must be received not later than the 1st of each month for advertisements to appear in the same month's issue.

PERSONAL

GERMAN TECHNICAL TRANSLATIONS by qualified Specialist with 16 years' experience. Excellent references. Priest, 114 Charlton Road, Westbury, Bristol.

Let SELSAW give you independent advice on Materials Handling, or act as your Plant Engineer. Write: Selsaw, 36 Venner Road, S.E.26. Materials Handling Consultants.

OSMOND

CUTTING OFF MACHINES

A. & S. OSMOND, LTD.
13 DOWRY SQ., BRISTOL

Telephone :
Bristol 27604

DING-DONG

HACKSAW BLADES

ask **YOUR DEALER FOR DING-DONG**

Manufactured by CHARLES BAYNES, LTD.

BLACKBURN, LANCS. **TEL. 6862**

PRESSURE DIECASTINGS

JOHN IRELAND (WOLVERHAMPTON) Ltd.

Bilston Street, Wolverhampton.
Telephone: 22134

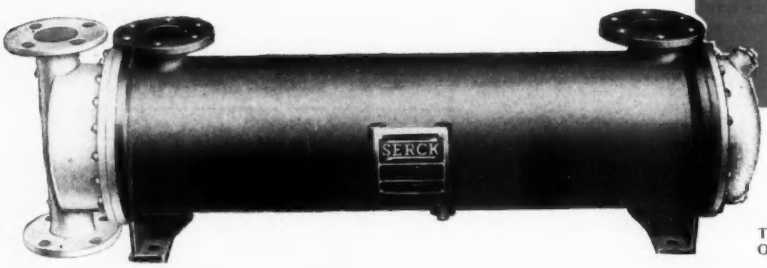
SERCK

HEAT EXCHANGE EQUIPMENT

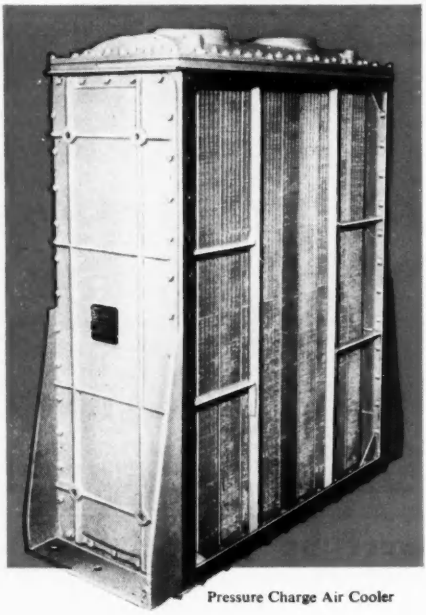
FOR EVERY INDUSTRY

OIL COOLERS, PRIMARY AND SECONDARY SURFACE

HEAT EXCHANGERS, CONDENSERS, AIR AND GAS COOLERS



Tubular Type
Oil Cooler



Pressure Charge Air Cooler

Diesel Locomotive Cooling Group

A first class Technical Advisory Service supports the products of the Serck Organisation into which have been embodied the intensive research and accumulated practical experience of thirty years and more.

SG/EI

SERCK RADIATORS LIMITED, WARWICK ROAD, BIRMINGHAM, II.

LATEST INDUSTRIAL LITERATURE

1. High-Capacity Roller Bearings. Excellently produced and illustrated, a 24-page booklet describes a comprehensive range of high-capacity roller bearings manufactured in five individual series and twelve distinct types, of which six have detachable inner races and two detachable outer races. All these bearings are produced to interchangeable limits, the detachable part of any bearing being interchangeable with the corresponding part of an equivalent bearing. The detachable race may be dispensed with, and the rollers can be made to track directly on a suitably hardened shaft diameter or housing bore.

2. Production Grinding Machines. Arranged for cylindrical grinding at high production rates, with tool-room finishes and accurate size repetition, the production grinding machines described in a well-produced and illustrated 8-page brochure are, in their basic form, semi-automatic and equipped with a spark-out timing device, enabling them to run through their cycle automatically, once they have been loaded. In addition, the controls are operated electro-hydraulically so as to take advantage of the benefits to be derived from the use of gauge sizing methods. A particular feature of this range of machines is the provision of a dwell, so arranged that it can be brought in at either or both ends of the stroke for individually variable periods up to 5 sec.

3. Corrosion-Resistant Piping Systems. Specially designed to enable complex piping systems to be built up easily and efficiently, the piping system described in a neatly produced illustrated 12-page booklet consists of standard parts in bores from 3 to 8 in. and includes all fittings normally required for a complete installation, including various lengths of straights, bends, tees, and standard reducers.

The system is so designed that it can, if desired, be connected to a very large number of existing systems with a minimum of difficulty. All parts are standard and interchangeable. Special items are not needed, and, by means of the standard reducers, complex systems of piping, from large to small bore, can be built up, dismantled, and rearranged as required.

4. Flexible Shafts. Issued by a well-known manufacturer, a comprehensive 62-page handbook discusses in detail the applications and advantages of flexible shafts, shaft-end fittings, flexible-shaft assemblies, flexible casings, and remote-control shafts. Besides an analysis of the characteristics of the flexible shafts, recommendations are included for the selection, installation, maintenance, and lubrication of flexible-shaft assemblies.

5. Automatic Pressure-Measuring Equipment. Providing remote indications of absolute or differential pressures to a high degree of accuracy, a range of automatic precision manometers is described in an 8-page illustrated brochure. Typical applications of these instruments, which consist of a control unit, a weighbeam unit, and additional remote indicator units, are wind-tunnel pressure measurement and control, precision barometric recording, and research in connection with steam and water turbines, jet engines, and centrifugal and axial-flow fans.

6. Power Presses. Details are given in a 4-page leaflet of a series of 40-ton power presses which incorporate a specially designed clutch to overcome all weaknesses experienced in the operation of the key type of clutch. The entire clutch assembly is indestructible and, apart from lubrication, needs no attention whatsoever. The body of each press is a solid high-duty alloy casting offering maximum rigidity, control being provided by a foot lever. Alternative control systems, such as electrical gear or pneumatic control, can be installed to suit customers' requirements.

7. Engineering Bearings and Laminates. Used for heavy-duty mill bearings, silent gears, railway wearing plates, marine stern tube bearings, and a number of other applications, a range of engineering bearings and laminates made of moulding resin compounds is described in a 12-page illustrated catalogue. These bearings are claimed to save power, simplify design, reduce the risk of shaft damage, and permit the accommodation of shaft misalignments.

8. Electric Brakes and Clutches. Details are given in a 16-page illustrated brochure of electric brakes and clutches used in a great variety of machines, including paper re-rollers, ring spinning frames, synthetic-fibre blenders, stretch-flattening machines, heavy looms, paper guillotines, and boring and cam-milling machines. The operating principles of the electric brakes and clutches are described and useful information is given on the speed-torque characteristics, design features, and application of these units, which have the advantages of fast engagement, controlled acceleration and deceleration, compact and simple design, and light weight.

9. Engineering Ceramics. Developed primarily as an electrical insulating material for sparking plugs, a range of engineering ceramics is presented in a 12-page brochure. High resistivity, high thermal conductivity, great mechanical strength, extreme hardness, good chemical properties, and low neutron capture are some of the main qualities of these ceramics. Their range of application includes shields for welding torches, insulation bridges, insulators of fire-detection systems, and housings of carbon-pile voltage regulators.

10. Crack-Detection and Demagnetizing Equipment. An illustrated 32-page catalogue, issued by a leading instrument manufacturer, incorporates various sectional lists and data sheets of a wide range of crack-detection equipment, including portable, mobile and universal crack detectors, bolt machines, magnetic-flux machines, heavy bar crack detectors, industrial-type transformers, demagnetizers, and crack-detector inks and jigs. A brief outline is also given of the principle and procedure of non-magnetic flaw detection.

11. High-Strength Friction Grip Bolts. Particulars are given in a 16-page brochure of high-strength friction grip bolts which, being greater in strength than rivets of the same diameter, can readily be substituted for rivets, without design changes. Faster erection, stronger joints, economy, permanent fastening, and less inspection are some of the advantages of the grip bolts described.

12. Conveyor Idler Systems. A well-produced illustrated 10-page brochure presents a range of conveyor idler systems, including troughing idlers and conveyor structures for bulk handling. The troughing roller assembly comprises a spring-steel shaft located to hollow stub-axle ends, on each of which is mounted a mild-steel trunnion and a shock-absorbing compression spring. The structures are of pressed steel construction and each structure can be dismantled into convenient units for transport.

MAIL THIS COUPON TO-DAY

THE ENGINEERS' DIGEST, 3.59
120 Wigmore Street, London, W.1

Date.....

Please send free and without obligation the literature indicated by the following circled numbers :

1 2 3 4 5 6 7 8 9 10 11 12

Name .....

Position .....

Company.....

Address .....

PRESSINGS

If you require pressings consult Ward (Metal Details) Ltd. We are specialists in the manufacture of all types of small and medium pressings of any shape, size and thickness, in steel, tinplate, copper etc. from which complete assemblies can be fabricated by welding, soldering or brazing.
Illustrated here are some examples of our products, and similar components can be produced to your own specification and design, and supplied in painted, plated or enamelled finishes.

WARD
(METAL DETAILS) LTD.

DARLASTON · STAFFS

CATALOGUE FREE ON REQUEST

JOSHUA HEAP & CO., LTD.
ASHTON-UNDER-LYNE · ENGLAND

HEAP'S
PATENT
AUTOMATIC SCREWING MACHINES
WITH ROTARY TANGENTIAL DIE HEADS

These machines have been especially designed for quantity production work, and they are capable of extremely fast rates of output. Outstanding features include Tangential Die Head, Hand and Automatic Releasing Motion, Automatic Closing Device, Automatic Pump, etc.

A full range of sizes are available